'TEEN-AGE' EDUCATION IN ENGLAND

IN March 1956 the Minister of Education asked the Central Advisory Council for Education (England) to advise him on the education of boys and girls between the ages of fifteen and eighteen. Under its chairman, Sir Geoffrey Crowther, the thirty distinguished members of the Committee have produced a report* which is worthy to take its place alongside such well-known predecessors as Hadow, Spens, Fleming and Norwood. It provides an all-embracing survey of the educational services available to the 'teen-age' population of England and Wales, as well as a penetrating analysis of the very considerable deficiencies in those services.

The Report has clearly been drafted by more than one hand, but by far the larger portion of it is written in the simple prose which would bring commendation from a Churchill or a Gowers. It is a report which, apart from the great importance of its subject-matter, asks to be read because of the attractive way in which it is presented.

Although the main recommendations are likely to stir up discussion which may at times become acrimonious, even the most robust critics of the Report would wish to endorse the Minister's gratitude to Sir Geoffrey and his colleagues for a Herculean task well done.

The Report is concerned with four sectors of educational provision for boys and girls between the ages of fifteen and eighteen—it is not concerned with the youth service, which is being examined separately by the Albemarle Committee—but will, almost certainly, become widely known for two main recommendations. These are the proposals to extend the age at which all children must remain at school—the age would be sixteen and the operative year would be between 1966–67 and 1968–69; and the introduction of county colleges according to a phased programme which would be completed within 15–20 years from now. There are, however, a number of other recommendations which could vitally affect the quality of education provided for teen-agers and which deserve close study. Few will quarrel with them, and in time nearly all should be implemented. Among them are the place of examinations in secondary modern schools, provision for those who leave full-time education at the age of sixteen and who require continued education with a vocational bias through day-release or sandwich courses, the way to combat specialization in school sixth forms (which the Council is prepared to support provided it does not mean over-specialization), the kind of teachers who will be required for the county colleges and the way to find and develop them. The cost of the required reforms would put no unbearable strain upon the Exchequer.

* Ministry of Education. 15 to 18: A Report of the Central Advisory Council for Education (England). Vol. 1: Report. Pp. xxxi+519. (London: H.M. Stationery Office, 1959.) 12s. 6d. net.

The decision to recommend that the school-leaving age should be raised in the late 1960's was based upon careful analysis of the place of education in a changing world, particularly that relating to secondary education. Whereas in 1894 only about 4 per cent of all boys and girls aged fourteen or fifteen were in school, and only 1 per cent of those aged sixteen and seventeen, to-day about two-fifths of all boys and girls aged 15–17 have education either full-time or for one day a week. Of the 2½ million children in maintained secondary schools, however, only 320,000 of them are aged fifteen or more; the Committee is concerned that the rest of the two million who could benefit should be given opportunities in full-time education as quickly as possible. In 1894 such a proposal would have been regarded as disastrous by parents whose children were regarded as winners of the extra bread which made life tolerable for the family. To-day, few families cannot support their children throughout a longer school education, a situation brought about by marked changes in economic social life of Britain. Compared with 1938, the community is about one-third richer in material wealth. The larger part of the rise in the national standard of consumption has been in the lower income-groups, a change reflected in the physique and health of school-children during the past twenty years. Other influences which make it easier to support a longer school life for children are earlier marriage, earlier child-bearing within marriage, smaller families, longer expectation of life and more opportunities of paid employment for married women.

The position of girls in the age-group studied has probably changed even more than that of boys. Child-bearing and child-care now represent a break in employment for married women rather than an end to it. This has important consequences for teaching as well as other careers. It points to the need for an education which encourages girls to qualify before marriage for careers and to develop interests which they can resume in later life. The early age of marriage points to a radically different concept of how girls of seventeen and eighteen should be treated and educated; more than 4 per cent of the girls with whom the report is concerned are married women.

The pressure of economic change bears upon school life in a number of ways. The earnings of young people have risen much faster in proportion than those of adults, and those who remain at school have to resist the lure of a high immediate wage; and to reconcile themselves to a lower earning capacity, until they are more than twenty years of age, than that enjoyed by those who leave at fifteen. It is evident, however, that they then catch up and go well ahead. Parallel with the need to stay at school as long as possible to obtain long-term economic

advantages, there is growing stress on the need for specialist qualifications and for a good general education to secure entry into an increasing number of occupations. This tendency may be reinforced by the fact that the proportion of young people to the whole population of working age is going to rise again after a long period of decline.

It is within this framework that the Committee sets its pattern for the future of teen-age education in the Britain of the future—for what is done in England is likely to be followed by Wales and, probably, Northern Ireland and Scotland. Education is regarded both as a duty that the State owes to its citizens—as part of the Welfare State—and as a means of increasing the economic efficiency of the whole community, and thus as a form of productive national capital investment. The Council welcomes the rapidly growing tendency for many secondary modern scholars to stay at school voluntarily until sixteen and hopes that, by 1965, about half the total numbers of secondary modern boys and girls will be taking extended courses beyond the age of fifteen. For the pupils for whom the General Certificate of Education examinations at Ordinary Level are unsuitable, the Committee recommends that external examinations should be developed experimentally on a regional or local basis.

With this assessment of the state of education and with these recommendations there will be few dissentients. With the major recommendation, that all children should stay at school until they are at least sixteen years of age, there is likely to be considerable disagreement. The Committee might well argue that it was only seeking to justify a decision of Parliament which is already on the statute book. There are many who would argue that all the experience with the lower streams of secondary modern school children since the Butler Act of 1944 should have led the Committee to recommend either that this section of the Act be repealed or postponed almost indefinitely, until much more pressing reforms to improve both the quality and quantity of British educational services be undertaken. Young people of England and Wales would gain much more if the extra teaching and material resources that will become available over the next decade were used to develop nursery schools, reduce the size of primary school classes, improve the quality of education for those taking City and Guilds and National Certificate courses—which in some local technical colleges is unbelievably bad and explains why many students fail to stay the course—to introduce speedily the much-heralded county colleges, to provide hostels so that university students may begin to live university lives and to develop day-release facilities for adult workers in industry.

The more this Report is studied the more one realizes how false a deduction is drawn from such lofty principles. The case for providing facilities for those two-thirds of secondary modern children who voluntarily wish to stay at school until they are sixteen or more and whose parents are equally keen is well made out. The case for compulsorily keeping those in school for whom the extra year (to fifteen) has already proved a burden to themselves and a source of frustration to those who try to teach them, appears to rest on the belief that 'Daddy-knows-best' and on the over-worked moral principle that what is good for some is good for all. Elsewhere in the Report we are told that the greatest number of juvenile delinquents is drawn from boys and girls who are in their last year of school, and that the desire to learn in many young people has only been awakened by their discovery at work of new ambition or personal inadequacy. All who have been concerned with *C* and *D* stream secondary modern youths at work will know how true this is, and would resist any attempt to inflict another year of misery on these unfortunate young people, for whom the academic approach has proved so inadequate in their development.

Here, as the reaction to the proposed raising of the school-leaving age has shown, they would be supported by all those teachers who teach day by day the scholars from lower streams of modern schools. These teachers frankly admit that they have been unable to find the way to interest and educate these boys and girls, and they believe that the only approach which is likely to be successful is through an integrated training scheme in a progressive firm with day-release facilities providing a clear vocational link with everyday work. It is a matter of regret that no member of the Crowther Committee teaches the lower streams in a modern school or deals with them directly in industry once they have left school. It is not without significance, however, that a strong minority of the Committee is far from happy about raising the school-leaving age for certain scholars who are physically or emotionally maladjusted to school life. They should persuade their colleagues to reconsider this controversial proposal and to take evidence from appropriate teachers in secondary modern schools, from industrial training officers concerned with the less intelligent type of existing school-leavers, and, above all, from the young people themselves not only when they are still at school but also six months after they have left.

Of the Committee's second main proposal—to introduce gradually a system of county colleges some fifteen to twenty years from now—the only disagreement will be the timing. The case for day-release was made out in 1918 and has not been contested. It was given a double blessing in 1944. When an important committee now reports that county colleges should come in time—after experiments in a few areas to gain experience and then by a spread region from region—it reveals either lack of conviction, lack of a sense of urgency, or the lack of moral courage to recommend that such a highly desirable reform is one about which Britain as a whole can no longer afford to procrastinate. To declare that more experience is needed before county colleges are developed nation-wide is scarcely complimentary to Bournville, Langside, Rowntree's,

Boot's College or the day-continuation activities which are now so well established under local education authorities like Liverpool and others. To infer that the scheme should wait for fifteen-twenty years is less than kind to the boys and girls of to-day and the next generation. To imply that the country cannot yet afford county colleges is flatly contradicted by the Committee's own declaration that despite the gain in the nation's wealth, we are proportionately spending no more on education—other than what is being done at the universities and in advanced technology—than we were in 1938. This is a bad reflexion on the use of the nation's resources and the amount we are prepared to spend on the education of our young people. Finally, the assumption that the country will have neither the teachers nor the material resources to introduce county colleges before the late 1970's must be set against all that has happened in the past twenty years. A Welfare State has been born in Britain, with health and social services of which we may be proud. The school-leaving age has been raised. Technical and university education have been transformed. Now with the nation's economic pulse beating strongly and steadily, the Crowther Committee asks the British people to wait twenty years before a generally agreed reform is introduced.

Despite major recommendations which are unlikely to get a smooth passage, this Report should be examined in its entirety. The section on specialization in the sixth forms of schools should be read by every university teacher, as well as headmasters and senior masters in secondary schools. The chapters on institutions and teachers should be made into a tutorial course for many members of local education authorities. Finally, because the Report has been specially prepared with the general public in mind, those concerned with mass communication media could perform a public service by presenting its main arguments and recommendations to as big an audience as possible. The Crowther Report will influence the quality of English education for many years to come.

THE BIRTH OF THE ROYAL SOCIETY

History of the Royal Society

By Thomas Sprat. Edited with Critical Apparatus by Jackson I. Cope and Harold Whitmore Jones. (Washington University Studies.) Pp. xxxii+456+78. (Saint Louis, Missouri: Washington University, 1958.) n.p.

OF recent years American scholarship has made many contributions to the history of science in the seventeenth century, prominent among many universities concerned being Harvard, represented by Bernard Cohen and his school, and Washington, the "University Studies" of which include in their wide range this period. The latest of these "Studies", which appears at a time when the forthcoming celebrations of the tercentenary of the foundation of the Royal Society make it of particular interest, is a re-issue of Thomas Sprat's "History of the Royal Society", furnished by the two editors with an introduction and extensive notes.

Thomas Sprat, born in 1635, graduated at Oxford, where he made some stir as a poet but none as a follower of the newly established pursuit of experimental science. He was, however, taken by Wilkins into the circle of active promoters and partisans of the new learning and was duly elected a Fellow of the newly formed Royal Society in 1663, which was no warranty of scientific prowess, as evidenced by the fact that the poets John Dryden, John Denham and Edmund Waller were admitted at the same time. He had close personal relationships with many of the distinguished founders of the Society and it was their influence, no doubt, that led him to write his "History of the Royal Society", which, published in 1667, is a history of the foundation of the Society and a defence against the scoffers; the misunderstanders, such as Sorbière; and the classical and religious carpers. The full title runs "The History of the Institution, Design and Progress of the Royal Society of London, For the Advancement of Experimental Philosophy". Sprat wrote largely as an apologist; as he says in his "Advertisment to the Reader": "and the Third (part) chiefly contains a Defence and Recommendation of Experimental Knowledge in General: So that it is only the Second Book that peculiarly describes their Undertaking". This "Second Book" which, however, occupies considerably more than half the volume, contains accounts of various scientific concerns of the Society, including, in particular, the "Method For making a History of the Weather", by Robert Hooke.

The book, written in a clear and pleasing style, attracted considerable attention, went into several editions, and was translated into French in 1669. In 1825, de Clugny wrote of it and the Royal Society: "Sprat mérita de devenir membre de cette société, et fut chargé par elle d'écrire son histoire, lorsqu'il devint nécessaire de se concilier l'esprit du public, qui croyait voir dans toute assemblée quelconque des sociétés pour rétablir la suprématie du pape. Son *Histoire de la société royale* . . . triompha de tous les pamphlets qui furent publiés contre elle. Cet ouvrage a été sans doute surpassé, quant aux faits, par Birch, et plus recamment par Thomson; cependant il est écrit avec tant de pureté et d'élégance, qu'il est encore recherché". The reference to the supremacy of the Pope is somewhat surprising!

The text in the issue now before us is a facsimile, actual-size reproduction of the text of the first edition of the book, and the "Introduction" discusses, clearly and with ample references, the circumstances which attended the publication of the book and the nature of its contents, as well as the style in which it is written. Among the notes, which bespeak wide reading, those on Stubbe's acrimonious attacks on the Royal Society are of particular interest. In a short appendix the origin and nature of these attacks are further discussed, with references which do not include, however, Harcourt Brown.

In the "Foreword" the editors remark that Thomas Birch's "History of the Royal Society" is 'crippled' for want of an index, a complaint with which every student of seventeenth-century science will wholeheartedly sympathize. In fact, no Ph.D. degree could be more serviceably earned than by the compilation of such an index which, if well done, would demonstrate the necessary scholarship. An important

earlier "Washington Study", Richard Foster Jones's "Ancients and Moderns", is likewise robbed of its full value by lack of an index. It is remarkable, in view of their specifically expressed opinion concerning Birch, that the editors should not have provided Sprat with an index. It is to be hoped that, should a re-issue of the book be called for, which is not unlikely, an adequate index will be furnished.

E. N. da C. Andrade

MICROBIAL VARIATION AND RUSSIAN EXPERIMENTS

Microbial Variation

Edited by V. D. Timakov. Translated from the Russian by G. H. Beale. Pp. x+202. (London and New York: Pergamon Press, 1959.) 40*s*. net.

THE book contains twenty-two papers by workers at the Gamaleia Institute of Epidemiology and Microbiology on the subject of 'directed variation'. The investigations described fall into two main groups: studies of the consequences of growing one bacterial species on killed cultures of a different species in an attempt to explain the formation of new species in bacteria; and examination of the changes brought about in organisms as a result of submitting cultures to the effects of antibiotics, bacteriophages, immune sera, etc., with the object of obtaining avirulent organisms capable of immunizing against pathogenic bacteria. The thesis put forward by Prof. Timakov in the introductory article is that organisms undergo variation under such conditions and that the nature of the variation can be directed by the environmental conditions imposed.

The more controversial material is contained in the first nine papers, concerned with the variation of an organism 'directed' by growth in the presence of dead cells of another species. Sufficient experimental detail is provided to allow some assessment of the significance of the results or to provide the recipes for attempts at reproduction of the experiments. In essence the experiments involve the growth of a large inoculum (10^{10} cells) of, say, *Escherichia coli* in a medium containing a suspension of killed cells (density 10^8–10^9 cells/ml.) of, say, *Salmonella breslau*. Transfers are then made at intervals of seven days (details of times and temperatures are not stated in all papers) and variants appear after 6–15 transfers. Variants isolated after 6–7 transfers are unstable and lose their 'new' properties on cultivation in normal media; variants isolated after the fifteenth transfer are stable and possess new, stable characteristics. Examination of the properties of these stable variants shows that they have acquired some of the characteristics of the killed cells on which they were grown. In the example cited, cells are obtained which are agglutinated by anti-*breslau* but not by anti-*coli* serum, and have become virulent. Other variants are found to have characteristics intermediate between those of *E. coli* and *S. breslau*. In his introduction, Prof. Timakov suggests that this is not the change of one species into another, since the *breslau*-like variant differs from *S. breslau* in being less able to produce infection when given orally; consequently, the experiments are said to demonstrate the production of a new species. It all depends on how you define a species, and there is considerable specious argument on this topic.

Such 'directed variations' are accomplished using various typhoid, paratyphoid, dysentery and coliform organisms. The editor remarks that "Certain objections which are not without foundation have been raised in connexion with this work . . . some workers believe that the bacteria . . . with characters of *S. breslau* were nothing more than germinated heat-resistant forms of *S. breslau*". One wishes that more details were provided to refute this belief; we are simply told that the suspensions were tested for sterility over a period of from fourteen days to six months. No practical details of bacteriological technique or quantitative data for controls are given. It is possible that something akin to transformation might be taking place in these experiments, and one paper deals with the directed variation of *E. coli* grown in the presence of nucleoproteins from pathogenic bacteria, but the work of Griffiths, Avery, Macleod and McCarty is dismissed in three lines as "inconclusive as proof of the occurrence of interspecific variation". There is little attempt to explain what might be happening in these experiments, other than to emphasize that the formation of new species can be directed in these various ways.

The book provides an interesting account of the work and views of certain Soviet biologists. Readers' reactions will be largely conditioned by their training and beliefs, but, at least, they now have sufficient data provided for them to attempt to direct variation for themselves.

E. F. Gale

NON-METALLIC BRITTLE MATERIALS

Mechanical Properties of Non-Metallic Brittle Materials

Edited by W. H. Walton. (Proceedings of a Conference on Non-Metallic Brittle Materials organized by the Mining Research Establishment of the National Coal Board in consultation with the Building Research Station (D.S.I.R.), and held in London, April 1958.) Pp. xi+492. (London: Butterworths Scientific Publications; New York: Interscience Publishers, Inc., 1958.) 90*s*.

THE variety of brittle materials is immense; some of them are heterogeneous even on a macroscopic scale, and some are anisotropic. Both features make their study difficult. Yet a knowledge of the properties of these materials is of great importance to a variety of industrial processes and it was with this idea in mind that the Mining Research Establishment of the National Coal Board and the Building Research Station organized a conference in April 1958. The Proceedings of this Conference present, probably for the first time, a series of papers which demonstrate the immense amount of work which is going on in this field and also emphasize the difficulties of elucidating the properties of brittle materials because of the presence of a large number of varying parameters. The format of the Proceedings in general follows the course of the conference.

At Session 1, "Strength in Compression, Tension, Bending and Shear" was considered and papers were presented giving experimental results on the strength of cubes of coal under uniaxial compression and under triaxial compression, the strength of bricks and a review of the micro- and macro-strength of glass. Other subjects considered were the strain-

stress relations and breakage of rocks, of their properties in conditions of triaxial stress and also the porosity and strength of brittle solids with particular reference to gypsum. These papers show a real attempt to correlate experimental results with theory, but it must be appreciated that many of the derived formulæ must, for the present, represent only an empirical interpretation of the properties and that much work is still to be done before the course of changes induced by applied stress can be forecast with any degree of accuracy.

Session 2 was devoted to consideration of "Elasticity and Creep". Papers were given on the elasticity, creep, shrinkage and the effect of rate of loading on some mechanical properties of concrete. The strength of ceramic materials under impact testing and sonic testing, and the stress-strain relationships in heavy clay products were discussed, while the factors effecting the thermal shock resistance of high-temperature materials were also considered. Measurements of the rheological behaviour of coal, together with the measurements of its dynamic mechanical properties, were compared with the paper presenting the elastic and plastic properties of carbon and graphite.

In the third session the conference went on to consider "Dynamic Loading, Impact and Fragmentation". Here papers were presented on the exploratory tests on the strength of concrete beams under pulse loads, impact testing and roller bit penetration. The breakage of natural materials was considered generally and in detail with the fragmentation of explosive detonated in stone blocks and with the partition of energy in a blasting shot. From the coal industry, studies of the size distribution and relationship between dust formation and coal strength provided an alternative approach.

Session 4 was devoted to a consideration of the "Action of Tools". There was a basic paper on friction between coal and metal surfaces and the forces required to penetrate the brittle material with a wedge-shaped tool. This was followed by a paper on the effect of lateral pressure on the cutting of coal by wedge-shaped tools and a consideration of both the theoretical and practical aspects of coal ploughing.

The discussions which followed papers and sessions have been admirably condensed and the whole volume will be an important work on the shelf of all who are concerned with understanding the processes in which the properties of brittle materials have to be taken into account.

DAVID TRAIN

CONSERVATION IN AMERICA AND AFRICA

Conservation of Natural Resources

Edited by Guy-Harold Smith. Second edition. Pp. xi+474. (New York: John Wiley and Sons, Inc.; London: Chapman and Hall, Ltd., 1958.) 68*s*. net.

The Conservation of Natural Resources

By Richard C. Haw. Pp. 256+36 photographs. (London: Faber and Faber, Ltd., 1959.) 30*s*. net.

IN every part of the world, though in varying degrees, the now obviously rapid increase in population consequent upon the fact that the spread of the knowledge and practice of death control has outstripped knowledge and practice of birth control is forcing attention on the need to conserve or to use wisely all natural resources. In the second edition of "Conservation of Natural Resources" the editor, Guy-Harold Smith, repeats the warning, "every individual company, or organization must share in the task of preserving the resource base upon which the American economy has been built. What is needed is an enthusiasm and an understanding of the essential nature of resources and the measures necessary to save from wasteful destruction our national heritage." It may be claimed that conservation in America was a by-product of the great economic depression of the nineteen-thirties which happened to coincide with disastrous seasons producing dust-bowl conditions over vast areas. Although ghost-towns already spoke eloquently of the exhaustion of mineral riches, abandoned farms of the retreat from the 'frontier' or 'pioneer fringe', conservation became identified with the prevention of soil erosion. An America which had been taught to think in square-mile blocks had to realize that Nature abhors a straight line, and to find answers in contour ploughing, strip cropping, restitution of grass cover thoughtlessly ploughed or woodland unwisely cleared. Now conservation has come to mean much more. The sixteen authors of this survey cover in its eight parts the land (with soil, irrigation, and grassland), the forests, water, minerals, wild life, recreational resources (linked with the conservation of man) and so to national, state and local planning.

Prof. S. S. Visher has an interesting introductory chapter on the public domain. It is perhaps not commonly recognized that practically all United States territory, except for the closely settled land of the original thirteen States, has, at one time, been Federal property. Forty-one per cent was sold to individuals for cash, 27 per cent granted to homesteaders, 13 per cent given to the railroad companies, 12 per cent given to education authorities, 1 per cent for canals, leaving 6 per cent, mainly of wet lands, which passed into ownership of the States. In 1956 more than 400,000,000 acres remained or had reverted to public ownership, being a total not far short of that in improved farm land. Thus Federal and State authorities are able to give a lead to conservation in the national forests and the great grazing lands as well as in national parks and Indian lands. But on privately owned land there are conflicting interests. Individual success is still measured largely by wealth: the obvious temptation is the quick fortune from 'mining', whether it be of minerals, the soil, or the forests. Technological advances will take care of the future and with the present over-production of agricultural commodities, those who preach conservation or teach it in the universities have by no means a pre-converted audience. This fine book should serve them well.

Although with an identical title, Mr. Richard C. Haw's book is very different. He is an instructor in the Domboshawa Government School at Salisbury in Southern Rhodesia: he writes essentially of the African veld and of the vital, urgent, necessity of its proper management if Africa is to survive. He uses the University Farm at Salisbury West as an example of planned layout; chapters which follow are practical guides to surveying, soil conservation, manuring, reclamation, road construction and water conservation. It is significant that he, too, does not forget the importance of wild life. Since so much of the world's problem lands lies in the seasonally dry sub-tropics, Haw's book deserves a wide public in other continents.

L. DUDLEY STAMP

THE ARMAMENT RESEARCH AND DEVELOPMENT ESTABLISHMENT

OPEN Days were held for the first time, during November 3–6, at the Armament Research and Development Establishment, Fort Halstead, Sevenoaks, Kent. This Establishment was part of the former Ministry of Supply and from November 23 has been part of the War Office. The recent changes in organization made in Government departments prevented the attendance of a Minister of the Crown, and the official welcome to visitors to the Open Days was extended by Lieutenant-General Sir John Cowley, controller of munitions.

The Open Days were planned with the object of inviting as guests a wide representative selection of people who had not previously had the opportunity of visiting the Establishment. Although security restrictions inevitably affected the scope of the exhibition, an excellent impression of the wide variety of work undertaken by the Establishment was afforded to visitors.

More than three thousand visitors attended the exhibition during the four days. During November 4–5 the visitors included Government officials and Service officers, representatives of Commonwealth countries, attachés at foreign embassies, members of local authorities, teachers at universities, technical colleges and schools, and representatives of industry. On November 6, the Establishment was open to families and friends of the staff. Previously, on November 3, the Establishment welcomed about fifty representatives of the national, local and technical Press and of sound and television broadcasting services. It was evident that the exhibition attracted very considerable interest from the general public.

The Armament Research and Development Establishment was created on January 1, 1955, by the amalgamation of the Armament Research Establishment and the Armament Design Establishment. The director of the Establishment is Dr. D. H. Black. The work of the first-named Establishment was surveyed in a previous article in *Nature*[1]. Up to the end of the Second World War, the history of the Armament Research and Development Establishment and its predecessors is essentially the story of the development of high-explosive munitions. The post-war years have brought considerable changes in the work undertaken. Under the direction of Sir William Penney, the development of Britain's first atomic bomb was undertaken within the Armament Research Establishment organization at Fort Halstead. This project led to the formation of the Atomic Weapons Research Establishment at Aldermaston, now a part of the United Kingdom Atomic Energy Authority. The part played by conventional weapons has been greatly affected by the development of nuclear explosives and weapons. The Establishment continues to undertake highly important work on conventional explosives and weapons, but has also extended its responsibilities to newer branches in the armament field.

The Establishment undertakes research, and designs and develops weapons and ammunition for all three Armed Services. Equipment for which it is responsible is extremely diverse; this includes guns together with their mountings and ammunition, fuses, small arms and their ammunition, mines and pyrotechnics. The Establishment is also concerned with work on guided weapons. Much basic research, both theoretical and experimental, is pursued. This research is not always immediately related to particular weapons, but often leads later to applied research aimed at the design, development or improvement of specific weapons. Basic and applied research are undertaken in a wide variety of fields; these include high explosives, ballistics, metallurgy, radiography, electronics, electronic computers, and the mechanics of fluids and solids. Much of the research done falls within the ambit of the physical sciences, and applications outside the armament field often occur.

More than a hundred individual items were listed in the guide to the exhibition, and these ranged from topics in basic research to actual demonstrations of weapons. It is not possible to give here an overall description. Instead, very brief accounts will be given of some current researches in a few important fields of general scientific interest.

Hypersonic Aerodynamic Flow

Laboratory investigations of the hypersonic flow of air past a body are very much more difficult than those of supersonic flow. Not only is it difficult to achieve the true stagnation temperatures at the correct Mach and Reynolds numbers of the flow, but also the entire physical picture is now considerably complicated by the occurrence of so-called real gas effects, such as dissociation, ionization and relaxation. The transition from the supersonic to the hypersonic régime occurs at a Mach number of about 5, but all the characteristic features of the latter régime may only become well developed at a much higher Mach number of, say, 15. The development at the Establishment of the light-gas gun-tunnel is an attempt to obtain a satisfactory laboratory facility for use in these investigations. A light gas at high pressure drives a light piston down a sealed gun barrel, and thereby gas (typically air) in front of the piston is compressed and is shock-heated. On completion of sufficient compression in the driven gas, this gas (now hot) is automatically released through a throat, to give expanded flow at Mach numbers between 8 and 15 in the working-section of the tunnel. The running-time in the working-section is about 50 ms. Schlieren photographs are taken, and total force, pressure and heat-transfer measurements are made of the gas-flow past models.

A low-density continuous-flow wind-tunnel with a plasma heater is in operation at the Establishment and is shown in Fig. 1. This facility caters for the simulation of conditions for aerodynamic flow at Mach numbers up to 12 and at altitudes up to 50 miles. Another facility is a small shock-tube in which shocks, travelling initially at Mach numbers of the order of 150, are set up by magneto-gas dynamic impulses.

Thermal Properties of High Explosives

Aerodynamic heating in high-speed flight may result in explosive components acquiring tempera-

Fig. 1. Low-density continuous-flow wind-tunnel

tures above normal. In order to examine the functioning and safety of these components under these conditions, the physical and chemical properties of high explosives are being investigated at elevated temperatures. These investigations include studies of thermal decomposition, thermal conductivity and sensitiveness.

Thermal decomposition of high explosives is investigated by the measurement of the rate of evolution of gas. This technique has been used particularly for RDX (cyclo-trimethylene trinitramine) and TNT mixtures. The main reaction is the first-order decomposition of RDX in solution in TNT. When RDX is suspended in a saturated solution of RDX in TNT, however, an additional reaction occurs in which it is believed that the TNT decomposes on the surface of the suspended RDX. The heat evolved during the decomposition of high explosives is determined by the rise in temperature of a copper canister, containing the explosive, placed in an electrical furnace the temperature of which is high enough to cause decomposition. In the case of tetryl (2 : 4 : 6-trinitrophenyl methyl nitramine) and TNT, the heat of decomposition is evolved in two stages, indicating the existence of a stable intermediate.

Thermal conductivity is determined by means of an apparatus in which use is made of Callendar's method. The examination of RDX/TNT 60/40 below the melting point of TNT shows that the thermal conductivity decreases with temperature rise.

Impact sensitiveness of a high explosive shows no variation with temperature if this is below its melting point. Above the melting point, sensitiveness depends upon the confinement of the sample. This is illustrated by the results obtained from tests made on small samples of molten high explosive placed upon an anvil. On impact, if the sample is ejected from the surface of the anvil, then the apparent sensitiveness is decreased, as compared with that of the solid high explosive; but when the sample is confined within a recess in the surface of the anvil, the reverse is the case.

Metallurgy

In the field of ferrous metallurgy, very high strength Si-Cu-Mo-V steels have been developed by the application of research into the effects of various alloying elements on volume changes at transformation temperatures, on martensitic breakdown during tempering, and on hardenability. These steels have tensile strengths greater than 140 tons/in.^{2}, good ductility and impact resistance, and are very resistant to tempering. The suitability of these steels for various potential applications is being evaluated; these applications include vehicle springs and torsion bars, aircraft high-tensile steel forgings and castings, missile components fabricated from sheet, and cold extrusion tools.

Research on materials at high temperatures has enabled considerable progress to be made in producing high-quality arc-melted molybdenum alloys and in working these alloys to bar, rod and sheet by means of forging, swaging, extrusion and rolling processes. The ductile–brittle impact transition temperature has been lowered to 225° C. by a metal-working process, but by using electron-bombardment melting for zone-refining, this temperature has been further substantially lowered to −140° C. in purified single crystals and to −80° C. in purified polycrystals. Progress is also being made in the protection of molybdenum at high temperatures, and promising results are being obtained with multi-layers of electro-deposited coatings in combination with ceramic.

The occurrence of repeated high stresses in certain engineering structures has necessitated design for a limited life. In this connexion, a push–pull machine has been developed for high-strain fatigue testing that is capable of producing failures in specimens down to within a single cycle.

Plasma-jet and transferred arc torches have been developed, and their use for the spraying of high melting-point metals as well as ceramics and other refractory materials is receiving considerable attention.

Ultra-high Speed Radiography

In certain armament investigations, the presence of high-luminosity, smoke and flying debris precludes the use of high-speed photographic techniques for observing events. Radiographic techniques must then be used instead. Techniques are now available for taking single-shot radiographs through approximately 2 in. of aluminium, with exposure times of less than 1 μsec. Some current research is concerned with the development of megavoltage systems which make it possible to penetrate 3 in. of steel, with the same exposure time. These techniques have proved useful in a wide range of explosion studies and have also been used in studies of industrial processes such as the flow of molten steel into moulds of complicated shape.

Other work involves the use of the Establishment's 5-MeV. linear-accelerator X-ray generator. This

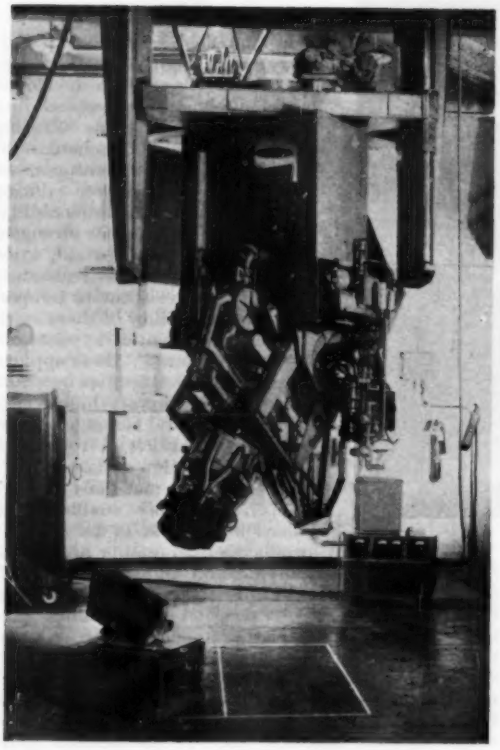


Fig. 2. 5-MeV. linear electron accelerator for radiography. (Penetration, 14 in. of steel; output, 600 röntgens/min. at 1 m.)

equipment (Fig. 2), although primarily used for the radiographic examination of heavy sections (up to 14 in. of steel, with a wire-sensitivity of 0·5 per cent), has also been used in strobo-radiographic work. The generator is operated with a pulse of 1·8 μsec. duration at a maximum frequency of 500 c./s. In this way, studies have been made possible of the valve and cam movements in a single-cylinder internal combustion engine operating at 1,800 r.p.m. Another application made of the technique is to the study of the response of enclosed systems to vibration.

Mechanics of Solids

The propagation of stress waves in solids and the mechanical properties of materials under dynamic conditions are subjects of fundamental importance in connexion with the investigation of certain problems of explosion or impact loading. Theoretical and experimental research is being done in this subject for various materials, including metals and visco-elastic solids such as brittle plastics and other high polymers. Of particular interest is the application of modifications of the Hopkinson pressure-bar technique to compression tests of softer metals and visco-elastic solids. In this type of mechanical test, a short cylindrical specimen is inserted in a 'split' pressure-bar. At one end of the pressure-bar, a stress pulse is generated by the detonation of a small explosive charge. Measurement of the change in time of the displacement produced at the other end of the pressure-bar enables stress–strain characteristics of the specimen to be derived for durations of applied loading of 10–50 μsec. The test has proved particularly useful in the study of visco-elastic solids. The dynamic value of Young's modulus that is derived in this way is in good agreement with values obtained from vibration and stress-wave propagation studies. For the softer metals, it is found that whereas the initial flow stress is significantly greater than that observed at low strain-rates, further deformation at these ultra-high strain-rates appears to be accompanied by unsuspected effects which are being further investigated. Considerable plastic flow in these materials occurs during the fall in stress, and in some cases at sufficiently large strain the dynamic stress–strain curve appears to fall below the static one.

Computational Techniques

A Ferranti Mark I* high-speed electronic digital computer, *Amos*, is used extensively to obtain numerical solutions to mathematical problems arising in the course of studies in a wide variety of scientific and engineering fields. Some examples are the mechanics of fluids and solids and the analysis of individual (and also systems of) weapons.

One particularly interesting recent development is a new computational technique for the numerical integration of systems of non-linear wave-propagation equations in three independent variables. The integration is made along bi-characteristic curves of the equations. Partial differential equations of this (or equivalent) type are of common occurrence in mathematical-physical investigations and methods of solving them are therefore extremely important. Examples occur in the theory of supersonic flow of fluids and also in theories of plastic flow in metals and other solids. So far, the technique has been applied only to the investigation of the steady supersonic aerodynamic flow around a body with the shape of a delta-wing. The theoretical predictions of pressure distributions agree very well with experimental results obtained in wind-tunnel tests. In principle, the technique could be extended to include equations of similar type but in four independent variables, but the computational work would then be severely increased.

Amos has also been used to make important advances in the design of lens optical systems. The important optical aberrations cannot all be reduced to satisfactory minima if the system contains only a few elements, and the consequent need for complex systems introduces difficult problems of design. The recent development of a new and efficient technique of optimization has made possible the reduction of these aberrations to several orders below that previously achieved.

In each of the above investigations a new analytical approach has provided the basis of the computational technique, but it is interesting to note that the use of the technique was possible only with the aid of the computer.

For certain types of numerical problems formerly solved on desk computing machines, it has been shown that the use of the full code of general purpose computers may often be advantageously avoided, particularly with less experienced programmers in mind. A simplified code, 'Intercode', has been developed for use on *Amos*, and several highly successful applications have been made of this procedure.

1 *Nature*, **172**, 1075 (1953).

GENERATION OF TEMPERATURES BELOW 1° K.

ON December 11, 1959, the Physical Society Low-Temperature Group held a symposium at the Institute of Physics on "Generation of Temperatures Below 1° K.", with Dr. P. H. Sykes as chairman. As on previous occasions, the programme was arranged to give plenty of time for questions and discussion. Very little unpublished work was presented, the purpose being chiefly to give an account of established principles and techniques to members of the Low-Temperature Group interested in this field. A detailed report of the proceedings is to be given elsewhere; the following is a brief outline of the material presented.

Following the chairman's introductory remarks, Mr. G. Davey (Clarendon Laboratory, Oxford) discussed the use of liquid helium-4 as a constant-temperature bath down to about 0·74° K., which is effectively the lower limit since the vapour pressure is very small there and is decreasing rapidly with temperature. If only a small pumping speed is to be used, the evaporation rate and hence heat influx to the bath must be drastically reduced, which entails the use of a narrow constriction in the pumping tube just above the bath, to avoid excessive heat influx through the superfluid film. Alternatively, to avoid a constriction, and allow a larger heat influx, a very large pumping speed must be used. Mr. Davey described an apparatus based on this principle, which used a pumping speed of 900 l./sec. and reached a temperature of 0·74° K. For comparison, a temperature of 0·75° K. can be obtained with a speed of 10 l./sec., and a suitably small constriction. The choice of method depends on the type of experiment and the equipment available.

The lower limit of constant-temperature baths can be extended to nearly 0·3° K. by use of the light isotope helium-3, owing to its much higher vapour pressure. Mr. M. Hobden (lately of the Clarendon Laboratory, now at the Royal Radar Establishment, Malvern) summarized the properties of ^{3}He relevant to this purpose, and described several ^{3}He cryostats, which, because of the scarcity of the substance, have come into use only in the past few years. In the 'single-shot' type, ^{3}He is first condensed into the cryostat and the vapour then pumped off to reduce the temperature. An alternative arrangement is the circulating type, wherein the gas is condensed in a vessel immersed in a helium-4 bath, and the liquid allowed to drip (through a needle valve or other high resistance) into the experimental space, where it evaporates and is pumped off, then compressed and re-condensed to continue the cycle. The latter method is more complicated but needs less ^{3}He, and can deal with a larger heat influx. There are no difficulties associated with a superfluid film in ^{3}He, but it must be carefully purified (notably of tritium and ^{4}He) and needs a fairly elaborate gas-handling system. On the whole, the cryostats are simple and convenient, and will undoubtedly come into increasing use.

Dr. E. Mendoza (University of Manchester) gave an outline of the principles and techniques of the adiabatic demagnetization method, whereby paramagnetic salts may be cooled to about 10^{-3}° K., and other substances, through them, to about 10^{-2}° K. The entropy of a paramagnetic salt may be reduced by applying a magnetic field, or by decreasing the temperature. The basic principle is therefore to magnetize the salt isothermally, lowering its entropy, and then to remove the magnetizing field isentropically, when its temperature must drop. The final temperature is proportional, ideally, to the ratio of the initial temperature to magnetizing field, typical starting conditions being 1° K. and 10^4 gauss. In practice, the final temperature is limited by the interactions between the ions, which may be reduced by using a magnetically dilute salt. Temperatures are measured by various methods, most commonly by determining the susceptibility of the salt, which is related to the temperature in the ideal case through Curie's Law. The absolute-temperature scale is established by experiments involving Carnot cycles. The cold salt will warm up at a rate determined by its specific heat and the heat influx, and one of the difficulties is frequently found to be the reduction of unwanted heat influxes due, for example, to mechanical vibrations or to desorption of exchange gas as the salt warms up. Dr. Mendoza also discussed means of obtaining isothermal conditions in the demagnetization region, for example, by isothermal demagnetization or by use of the magnetic refrigerator. Another problem encountered is the design of 'heat switches' to make and break thermal contact, among which are the superconducting, 'bath plug', and ^{3}He rectifier types. In the discussion, Dr. K. Mendelssohn (Clarendon Laboratory) mentioned the use of adiabatic magnetization of a superconductor for obtaining temperatures of a few tenths of a degree.

The more esoteric technique of nuclear adiabatic demagnetization was described by Dr. N. Kurti (Clarendon Laboratory). Since the limiting temperature in the demagnetization method is determined by the magnetic interactions present, much lower temperatures can be reached by reducing these, namely, by choosing a substance the entropy of which at low temperatures is determined not by the electron spins but by the nuclear spins, which have magnetic moments smaller by a factor of about 10^3. To obtain the same entropy reduction as in the electron spin case, it is necessary to use a ratio of magnetic field to initial temperature about 10^3 times larger. In one experiment, for example, a specimen of copper was demagnetized from 0·012° K. with a field of 30 k. gauss, the low starting temperature being achieved by 'ordinary' demagnetization of chrome potassium alum. Dr. Kurti explained some of the problems of technique, and of interpretation of results, emphasizing that the lowest temperature reached, about 10^{-6}° K., was that of the nuclear-spin system, not of the lattice or the conduction electrons. To obtain cooling of the bulk material, it would be necessary to insert a heat switch between the electronic and nuclear stages. Even without this, it should be possible to cool, and do experiments on, the conduction electrons down to at least 10^{-3}° K.

Dr. H. London (Atomic Energy Research Establishment, Harwell), in a paper entitled "More Abstruse Techniques", analysed the possibility of using the reversible adiabatic dilution of liquid ^{3}He

with liquid ^{4}He. Such a dilution, in analogy with the adiabatic expansion of a perfect gas, leads to a cooling which is enhanced by the latent heat of mixing. A complete analysis of the method is not simple, and the possibilities may be limited by the presence of the phase separation region in liquid ^{3}He–^{4}He mixtures. In practice, reversible dilution can be achieved by introducing superfluid ^{4}He through a superleak into pure liquid ^{3}He, or into a ^{3}He–^{4}He mixture. One might expect to work with temperatures around 0·1° K.—perhaps even lower—although no direct experiments have been carried out at this stage. An advantage of the method would be that it does not require the use of magnetic fields; on the other hand, if it were to be used as a continuous refrigerator the system would be quite a complicated one.

The symposium ended with a description by Dr. D. F. Brewer (Clarendon Laboratory) of two recent sets of experiments on helium-3 carried out at the Ohio State University, using the adiabatic demagnetization method for cooling. Down to 0·085° K. the specific heat of the liquid was found to have no anomaly such as occurs with liquid helium-4, and appears to vary linearly with temperature below about 0·1° K. In this respect the liquid behaves like a Fermi–Dirac gas with effective mass twice that of a ^{3}He atom. In other respects, such as its increase of specific heat with pressure below 0·16° K. and its negative expansion coefficient, it is unlike a perfect Fermi-Dirac gas. These results can be explained theoretically. Experiments on the melting curve confirm by direct measurement the presence of a minimum at 0·32° K. which had already been inferred from other experimental and theoretical sources. The region of the melting curve below the minimum is inaccessible to measurement by the usual methods, and hence evaded observation for some time; the measurements described were carried out by use of a strain gauge as pressure transducer, which circumvents this difficulty. They confirm the existence in solid helium-3 at low temperatures of forces additional to the magnetic spin-spin interaction.

D. F. Brewer

FOOD RESTRICTION AND SALT PREFERENCE IN RATS

By HANS KAUNITZ, LESTER M. GELLER, CHARLES A. SLANETZ and RUTH E. JOHNSON

Department of Pathology, Institute of Comparative Medicine, and the Division of Neuropathology, College of Physicians and Surgeons, Columbia University, New York

MOST human beings, as well as many other animals, will consume an appreciably greater amount of salt, if it is available, than is required for survival, growth or reproduction. The possible relationship between heavy salt intake and hypertension has been recently re-emphasized[1], while the beneficial effects of high salt intake in such conditions as profuse sweating[2], and in adrenal[3] and certain cases of renal[4] insufficiency are well known. It has been suggested that the salutary action of salt in these cases may not be due to a simple replacement phenomenon, but rather to the consequences of a stimulating action of sodium chloride upon certain body tissues[5]. Presumably such an enhancing effect of salt might also influence certain behavioural responses of the organism to its environment.

The preference of rats for solutions of sodium chloride, particularly in isotonic concentration, as against water, has been well established[6–9]. Our interest in this area lay in investigating possible differences in the level of fluid intake of rats drinking salt solution, as compared with fresh-water drinkers, under conditions of marked and moderate food restriction, and also in studying the possible effects of excessive salt intake upon survival, growth (body-weight), reproduction, and weights of certain organs. Studies of the speed of eating and maze activity of drinkers of salt solution will be reported later.

Male rats from our stock colony (Columbia–Sherman strain, arbitrarily bred as a closed colony for at least fifteen generations) were maintained from weaning (24 days of age) on a purified diet[10] consisting of 30 per cent alcohol-washed casein, 20 per cent lard, 44 per cent dextrose, 2 per cent cellulose, 0·5 per cent calcium carbonate, and liberal amounts of all known vitamins. To this diet was added 4 per cent of U.S. Pharmacopeia salt mixture XIII, containing enough sodium chloride to allow a level of approximately 0·15 per cent of the last named in the final diet. This quantity of salt had been found to be adequate for permitting maximal growth, survival and reproduction in our rat colony, and it was our intention in these experiments to avoid any limiting factors in the diet *per se* which might interfere with such functions.

Each animal was housed in a roomy cage, on wood shavings. The cages were supplied with water bottles bearing machined stems which minimized dripping sufficiently to permit reliable determinations of liquid intake to be made by weighing the bottles to an accuracy of $\pm$ 1 gm. All young were earmarked, and then weighed at 28, and again at 35, days of age. Two matching groups of forty rats each were formed having identical average weights at 28 and again at 35 days of age, a procedure which strongly implied similar average growth-potentials in both groups. One group continued to drink water, and the other was offered a bottle of 1 per cent salt solution and one of water.

Shortly thereafter an attempt was made to equate the groups with respect to temperamental or personality characteristics. Each rat was placed in a Lashley III maze (eight *culs de sac*)[11], and observed

Table 1. Average Daily Fluid Intake of Rats Drinking 1 per cent Salt Solution and Water, or Water alone, under Different Conditions of Availability of Food

Group	No. of rats	Age* (days)	Weight* (gm.)	Average daily fluid intake (c.c)								
				Free access to food (14 days)			Weight reduction (7 days)			Maintenance of reduced weight (21 days)		
				Water	1 per cent salt	Total	Water	1 per cent salt	Total	Water	1 per cent salt	Total
Salt solution and water	20	282	471 ± 18†	7 ± 1·2	34 ± 3·6	41 ± 3·1	6 ± 0·8	59 ± 5·7	65 ± 5·5	5 ± 0·8	65 ± 5·5	70 ± 5·7
Water only	20	282	459 ± 21	25 ± 1·2	—	25 ± 1·2	23 ± 2·3	—	23 ± 2·3	25 ± 1·6	—	25 ± 1·6

* Age and mean weight of animals at beginning of fluid intake determinations (day 1 of period of free access to food).
† Standard error of the mean.

for 5 min. on each of four consecutive days. As possible indicators of the nature of the response of each animal to a novel situation, the time required to leave the starting box, the number of alleys investigated, and the distance traversed toward the goal box, as well as the number and consistency of boluses dropped—an 'emotional' indicator to some workers[12]—were recorded. From the originally matched groups of forty rats each, two sub-groups of twenty were selected on the basis of the similarity of their behaviour in the maze. The final groups, therefore, consisted of twenty animals each, well matched as to age and growth tendency, and perhaps to a lesser degree, as to certain temperamental or personality characteristics.

Approximately eight months later, measurements of liquid intake under different conditions of availability of food were begun. The average daily liquid intake of the salt and water groups was determined over a 2-week period, with food freely available. Both groups consumed approximately 12–14 gm. of food daily during this time. Thereafter the animals were placed on a deprivation schedule designed to reduce their weight and then maintain it at the lowered level. To accomplish this, 5 gm. of food were given each animal daily for 4 days. During the next three days they received only enough food (1–8 gm.) to reduce their weight to 85 per cent of the weight at the beginning of the determinations[13]. During the next three weeks the weight of all rats was kept constant, within a daily average fluctuation of ± 2 gm. per group, by supplying them with an average ration of 9 gm. per day. Determinations of liquid intake during the periods of weight reduction and maintenance were made. Thereafter the animals were given food *ad libitum* and later used for other studies.

As seen from Table 1, the average daily fluid intake of the group drinking only water remained almost constant during the three different periods of food availability. The salt group behaved differently. As expected, these animals, when offered a choice between tap water and a 1 per cent salt solution, strongly preferred the latter under all conditions. Their fluid intake under ordinary conditions, that is, with food freely available, was significantly higher than that of the water group ($t = 4{\cdot}82$; $P < 0{\cdot}001$). During both periods of food restriction the average daily intake of fresh water in the salt group did not vary significantly from the volume consumed during the period of free access to food. The consumption of 1 per cent salt solution, however, rose markedly, so that the average number of c.c. drunk daily during the seven days of weight reduction and the fourteen days of maintenance of reduced weight was almost twice that consumed under ordinary cage conditions.

Thus the results are clear in indicating that when rats are deprived of their normal ration of food their consumption of water does not change, but when given the opportunity, their consumption of a 1 per cent salt solution will rise steeply, so that their average daily total fluid intake is almost three times (Table 1) that of animals drinking water only.

The average daily food ration necessary to maintain the animals at the desired level of weight reduction (85 per cent of initial weight) varied from 8·6 ± 0·3 to 10·4 ± 0·4 gm., with a mean ration, as mentioned earlier, of 9 gm. in both the experimental and control groups. This suggests that the increased intake and excretion of salt and water were carried out efficiently by the salt solution drinkers, since additional food or caloric intake was not required by this group.

After one year of observation, no significant difference between salt and water drinkers was noted in survival, growth (gain in weight), or fertility (Table 2). A separate group of twenty female rats, maintained on a free choice of 1 per cent salt solution and/or water for one year, but not included in any of the other studies, proved also to be fertile. Litters from male and female salt drinkers, each mated with a fresh-water drinker of the opposite sex, were fully the equivalent of control progeny in number, survival, and weight at weaning. It is not impossible, however, that differences in survival and fertility between salt and water drinkers would have become apparent had the observation period been carried beyond one year.

Determinations of the weights of heart ventricles and kidneys after food deprivation were made on two additional series of rats, not included in the fluid intake studies. To provide a background of organ-weights in our rat colony against which to evaluate these findings, the organ-weights of 427 normal animals, ranging in weight from 60 to 700 gm. were determined. A log–log plot of organ versus body-weight gives a positive straight-line relationship between the two over wide ranges of body-weight, with a uniform spread (standard deviation) about

Table 2. Weight, Survival and Fertility of Male Rats offered a 1 per cent Salt Solution and Water, or Water Alone, after One Year of Observation

Group	No. of rats	Average weight (gm.) ± standard error	No. alive		No. fertile
Salt solution and water	36	491 ± 22	26	$\chi^2 = 2{\cdot}432$ df = 1 $P > 0{\cdot}10$	26
Water only	32	486 ± 17	28		28

* These groups are not identical with the animals used in the fluid intake studies, since a number of those were killed for other determinations. Comparable male animals, selected and maintained in the same way as were the fluid intake groups, but not subjected to the deprivation schedules, have been included instead.

Table 3. Analysis of the Effect of Food Restriction upon Heart and Kidney Weights in Rats Drinking 1 per cent Salt Solution and Water, or Water only

Group	No. of rats	Average weight at death (gm.)	Average weight of heart ventricles (gm.)		Average weight of both kidneys (gm.)	
Salt solution and water	30	293 ± 4·8*	0·73 ± 0·014	$t = 4·49$ $P < 0·001$	1·9 ± 0·05	$t = 3·12$ $P < 0·002$
Water only	30	291 ± 4·7	0·65 ± 0·011		1·7 ± 0·04	

The six groups of ten rats each, seen in Fig. 1, have been re-grouped into two series of thirty each for computational purposes. Animals were killed at end of period of maintenance of reduced weight, at 124 days of age.
* Standard error of the mean.

each mean weight[14]. In Fig. 1, the solid lines represent the normal relationships of heart ventricle and kidney weights to body-weights, over the body-weight range of the animals in the current experimental series. The dotted lines represent the standard deviations of the plotted mean organ weights.

Experimental results are presented in Fig. 1 as points, each of which represents the mean organ weight of ten animals, killed directly after termination of the period of maintenance of reduced weight, at 124 days of age. The salt animals were offered a choice of 1 per cent salt solution or water from weaning (24 days), while the others received water only. It can be seen that the effect of food restriction was to reduce the average weights of ventricles and kidneys of both salt and water drinkers, as compared with colony control results, but the degree of weight loss of both organs was significantly less in the salt solution group than in the straight water drinkers (Table 3). A second series (not shown in Fig. 3) of 50 salt solution drinkers and 53 water-drinking rats was kept on the food deprivation and maintenance of reduced weight schedule already described, and then permitted to eat freely for 3–16 weeks thereafter. No deviations of their ventricle and kidney weights from those of the colony controls were found. Both groups ranged, in age, from 84 to 455 days, and in

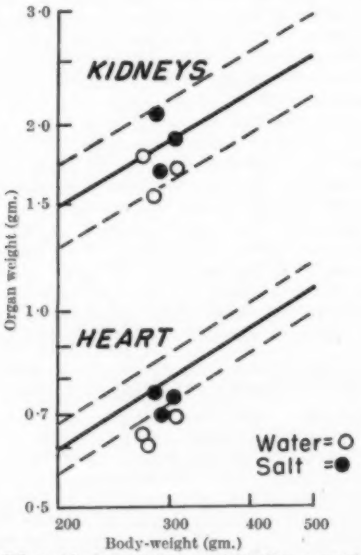


Fig. 1. Effect of food restriction on weight of heart ventricles and kidneys in rats drinking 1 per cent salt solution and water, or water only. Each point represents the average organ-weight of 10 animals. The solid lines are log–log plots of organ- vs. body-weights of normally reared animals; the broken lines represent the standard deviations of these plots

average weight from 310 to 512 gm., at the time they were killed for determination of organ weights.

No differences in the weights of the adrenal glands, livers or thymus glands were noted between the salt drinkers and the rats drinking water. Under food restriction the weight of the adrenals increased by about 20 per cent in both groups, and that of the liver and thymus gland decreased by 30 and 50 per cent, respectively. In the groups that were given free access to food for 3–16 weeks following reduced food intake, the weights of these organs closely paralleled normal values.

Taken together these results document certain consequences (or the lack thereof) of freely chosen, long-term ingestion of salt. Consumption of 1 per cent salt solution for periods of more than a year had no effect upon the weight of the heart ventricles or kidneys of normally reared rats. Under conditions of food restriction the loss of weight of these organs was significantly reduced in the presence of salt intake. Survival and body-weight were not affected after one year of drinking 1 per cent salt solution, nor was the fertility or the quality or number of offspring of such animals altered.

During the period of reduced weight maintenance the salt and water groups both required the same amount of food to maintain their weights. Yet the animals given a free choice of 1 per cent salt solution or tap water increased their average daily fluid intake (consisting overwhelmingly of 1 per cent salt solution and *not* water) to 25 per cent of their body-weight (Table 1), while the intake of the water group remained stable.

We believe these results provide an example of rapid learning in the rat, where a lack (food deprivation) in one aspect of consummatory behaviour (eating) leads to a marked change (increased intake of salt solution) in another consummatory response (drinking), in the presence of adequate neural equipment, and experience (rapidly acquired preference for 1 per cent salt solution). The rat's preference for 1 per cent salt solution is manifested quickly, and is maintained consistently under normal cage conditions. (We do not believe it was necessary to give the animals a free choice of salt solution or water from the time of weaning in order to demonstrate these findings. The long-term intake of salt solution was permitted only for the purposes of the toxicity studies.) When the amount of food available to the rat was curtailed, its intake of another appetitively stimulating substance, salt, increased, but only to a certain level. These animals were not starving, and presumably the maximal satiating effect of salt solution was reached at that level.

This interpretation is supported by the results in Table 1, which indicate that during the 7-day period of weight reduction, the average daily intake of salt solution was 59 c.c.; but during the next 21 days

of maintenance of reduced weight, when the animals actually were receiving a greater amount of food than before, though still less than under *ad libitum* feeding, the intake of salt solution became stabilized at 65 c.c. Thus the consumption of salt solution was approximately the same under both conditions of food reduction, but with ample food available, it was markedly lower (34 c.c. a day). That this effect is transitory and related to the availability of food was further shown by observation of the rats after their return to *ad libitum* feeding, when their average intake of salt solution dropped to initial levels.

Hebb has presented a theoretical account of the role of learning in hunger, eating, and the cessation of eating[15]. He illustrates some of his points with the salted nuts phenomenon, where once they are tasted, it becomes increasingly difficult to let them alone. Hunger has increased, but how? As Hebb says, ". . . a lack of food cannot be increased by eating something, and stomach contractions are stopped by chewing and swallowing" (ref. 15, p. 200). Nor is it feasible to believe that a taste of salted nuts increases appetite and not hunger, for as Hebb points out, the distinction between the two, at least in terms of an understanding of the physiological control of eating, is highly artificial. If, however, one considers hunger, ". . . to be neither a particular condition of the body, nor a set of sensations from the stomach, but an organized neural activity that can be aroused (like any other conceptual process) in several ways . . ." (ref. 15, p. 203), the role of salt as a provocative agent in consummatory activity is somewhat clarified. Drinking only tap water evidently did not provide an associative link for the animals, in these experiments, between the consummatory response made and appetite. Put another way, it did not serve (as did salt) to arouse a pattern of learned behaviour associated with appetite and/or hunger.

The recognition of the role of learning or experience in activities generally viewed as responses to internal needs, or primary biological drives, will require a re-appraisal of current ideas about hunger and thirst, and perhaps of greater significance for behaviour theory, of the concept of motivation, in general. The increasing recognition that the functional division of the nervous system into 'central' and 'peripheral' (or 'sensory') mechanisms is probably unwarranted with regard to behaviour should be of particular pertinence in this connexion[16]. Recent work by a number of investigators[17–19], as well as a current review[20] and a book[21], emphasizing the role of experience in the determination of patterns of consummatory behaviour, lend additional support to these conclusions.

This work was supported in part by research grant *B*-1620 (awarded to the Division of Neuropathology) from the National Institute of Neurological Diseases and Blindness, U.S. Public Health Service.

[1] Dahl, L. K., *Nature*, **181**, 989 (1958).
[2] Bass, D. E., and Kleeman, C. R., Quartermaster Climatic Res. Lab. Rep. No. 214, Lawrence, Mass. (1953).
[3] Loeb, R. F., *Proc. Soc. Exp. Biol. Med.*, **30**, 808 (1933).
[4] Blum, L., and Grabar, P., *C. R. Soc. Biol.*, **98**, 527 (1928).
[5] Kaunitz, H., *Nature*, **178**, 1141 (1956).
[6] Richter, C. P., "L'Instinct dans le Comportement des Animaux et de l'Homme" (Masson, Paris, 1956).
[7] Bare, J. K., *Amer. Psycholog.*, **2**, 331 (Abst.) (1947).
[8] Weiner, I. H., and Stellar, E., *J. Comp. Physiol. Psychol.*, **44**, 394 (1951).
[9] Young, P. T., and Falls, J. L., *J. Comp. Physiol. Psychol.*, **49**, 569 (1956).
[10] Kaunitz, H., *Wien. Med. Wochschrift.*, **102**, 356 (1952).
[11] Lashley, K. S., "Brain Mechanisms and Intelligence" (Univ. Chicago Press, Chicago, 1929).
[12] Hall, C. S., *Psychol. Bull.*, **38**, 909 (1941).
[13] Kaunitz, H., Slanetz, C. A., Johnson, R. E., and Guilmain, J., *J. Nutrition*, **60**, 221 (1956).
[14] Stoerk, H. C., and Zucker, T. F., *Proc. Soc. Exp. Biol. Med.*, **6**, 297 (1946).
[15] Hebb, D. O., "The Organization of Behavior. A Neuropsychological Theory" (Wiley and Sons, New York, 1949).
[16] Teuber, H. L., "Ann. Rev. Psychol.", **6**, 267 (1955).
[17] Ghent, L., *J. Comp. Physiol. Psychol.*, **50**, 172 (1957).
[18] Lawrence, D. H., and Mason, W. A., *J. Comp. Physiol. Psychol.*, **48**, 267 (1955).
[19] Baker, R. A., *J. Comp. Physiol. Psychol.*, **48**, 37 (1955).
[20] Cofer, C. H., "Ann. Rev. Psychol.", **10**, 173 (1959).
[21] Bindra, D., "Motivation: A Systematic Reinterpretation" (Ronald Press, New York, 1959).

NEWS and VIEWS

Radio Research in the D.S.I.R.: Dr. R. L. Smith-Rose, C.B.E.

On September 30, Dr. R. L. Smith-Rose will retire as director of radio research in the Department of Scientific and Industrial Research. Dr. Smith-Rose has been associated with the work of the Radio Research Board of the Department since the formation of the Board in 1920. In 1919 he joined the scientific staff of the National Physical Laboratory as a member of the Electricity Department, and a few years later, when the new 'Wireless Division' of the Department was formed, Smith-Rose was appointed scientific officer-in-charge. This was the nucleus of the Radio Division of which he became superintendent in 1939. In 1948 he was appointed to the new post of director of radio research in the Department of Scientific and Industrial Research, with headquarters at the Radio Research Station, Slough. This Research Station is now known internationally for its work in the fields of radio wave propagation, tropospheric and ionospheric research, radio atmospheric noise, radio standards and measurements and, more recently, for observations and predictions on artificial Earth satellites. Smith-Rose's personal research activities have included fundamental and pioneering investigations in radio direction finding, studies on the electrical properties of soil and sea water, and on the propagation of radio waves over the ground and in the troposphere. He has always been very active in national and international radio organizations and has held numerous posts of distinction. He was chairman of the Radio Section of the Institution of Electrical Engineers in 1943, and has been awarded premiums on five occasions for original papers read before the Institution. He is a Fellow and former vice-president of the Institute of Radio Engineers (New York) and is an honorary member of the Institution of Radio Engineers, Australia. He is a vice-president of the International Scientific Radio Union. In 1947, Dr. Smith-Rose was awarded the U.S. Medal of Freedom with Silver Palm for his service in scientific research and development, and for co-operation with American scientists. He was made C.B.E. in 1952.

Mr. J. A. Ratcliffe, C.B.E., F.R.S.

Mr. J. A. Ratcliffe has been appointed to succeed Dr. Smith-Rose. At present Mr. Ratcliffe is reader in physics in the University of Cambridge and head of the Radio Section at the Cavendish Laboratory. He entered Cambridge in 1921 with an open scholarship to Sidney Sussex College and first joined the Cavendish research group in 1924, working with Appleton in some of his earliest investigations of the ionosphere. In 1927 he was appointed demonstrator at the Cavendish Laboratory and in the same year elected a Fellow of Sidney Sussex. During the War, Ratcliffe was employed on various aspects of research and development in radio, mainly at the Telecommunications Research Establishment, Malvern. For a year he was seconded to the Army to start the radar school at Petersham and later returned to the establishment to undertake responsibility for establishing and running the Post-Design Service organization which was concerned with performance problems of radar equipment under service conditions. In 1947 he was made O.B.E., for this war-time work, and in 1959 C.B.E., for advisory work to the Ministry of Supply. In 1951 he was elected a Fellow of the Royal Society, and at the present time he is president of the Physical Society, vice-chairman of the Electronics and Communications Section of the Institution of Electrical Engineering, and overseas vice-president of the Institute of Radio Engineers (New York). Apart from the war years, Ratcliffe's work has been carried out at Cambridge where he has built up a major radio research school. Over a period of thirty-five years he has made extensive researches on the propagation of radio waves and on the ionosphere.

U.K. Atomic Energy Authority: Mr. H. Cartwright, M.B.E.

Mr. H. Cartwright, at present serving as deputy director of industrial power in the Development and Engineering Group of the United Kingdom Atomic Energy Authority at Risley, has been appointed director of industrial power. Mr. Cartwright was born in 1919 in Manchester. He was educated at William Hulme Grammar School, Manchester, and at St. John's College, Cambridge, where he took a first-class honours degree in the Mechanical Sciences Tripos in 1940. During the period 1942–46 he was a signals officer on ground radar stations in the Royal Air Force, reaching the rank of flight lieutenant. After working for the Decca Navigator Co., Ltd., Brixton, and the English Electric Co., Ltd., Stafford, he joined the Atomic Energy Division of the Ministry of Supply at Risley in 1949 as a design engineer. In 1954, on the formation of the Atomic Energy Authority, Mr. Cartwright became an assistant chief engineer in the Authority's Industrial Group at Risley. He was promoted to chief engineer in 1955, assistant director in 1956 and deputy director of industrial power in 1958.

International Atomic Energy Agency: Research Grant

The first research grant under the Exchange and Training Programme of the International Atomic Energy Agency has been awarded to Dr. R. P. Agarwala. Dr. Agarwala has graduated from the Agra College, India, and the Imperial College of Science and Technology in London; he has published a number of papers on metallurgy. Dr. Agarwala will undertake a year of research in the field of solid-state physics and chemistry at the Massachusetts Institute of Technology. These research grants are awarded mainly to scientists with considerable research experience, who are already working in their own countries on a promising line of research which cannot be developed fully there because of lack of equipment or laboratory facilities.

Silver Jubilee of *Science and Culture*

The Silver Jubilee issue of *Science and Culture* (**25**, 1), organ of the Indian Science News Association, is one of which its sponsors may justly be proud. Besides a brief and modest history of the Association itself, there is an account of the rise of scientific research in India with tributes to those pioneers who did so much in difficult times. Among the contributors to the Silver Jubilee edition are distinguished men of science from various parts of the world. Hans von Euler, of the University of Stockholm, examines experimental work on nuclear acids and nucleotides, and A. I. Oparin, of the Moscow Academy of Sciences, discusses the origin and development of life on Earth. J. D. Bernal considers priorities and phasing in the use of science, while Ivan Matels, of the Czechoslovak Academy of Science, describes research and production of antibiotics in Czechoslovakia. There are also a number of articles by eminent men of science from India. The journal is published monthly from 92 Achanya Prafullachandra Road, Calcutta 9, at an annual subscription rate of £1.

Alcohol and Road Safety

Although the problem of alcohol and road safety has been much in the public eye, there has hitherto been little precise evidence as to the effects of small quantities of alcohol on driving skill. For this reason, the careful study by Prof. George Drew and his colleagues recently published by the Medical Research Council ("Effect of Small Doses of Alcohol on a Skill Resembling Driving", by G. C. Drew, W. P. Colquhoun and Hazel A. Long. M.R.C. Memorandum No. 38. H.M.S.O. 7*s*. 6*d*. net) will attract widespread interest. This report describes the effects of small doses of alcohol (the highest being roughly equivalent to only five fluid ounces of whisky for a man of average weight) upon performance on the 'Miles motor driving trainer'—a complicated tracking task which has a good deal in common with actual driving. It was found that the mean error of forty subjects on the test increased significantly with increasing blood alcohol, the shape of the curve being strikingly similar to the blood and urine alcohol curves. On the other hand, the average speed of 'driving' showed no significant change. Marked differences between subjects were however observed, and the authors rightly place weight on temperamental factors as governing individual reactions to alcohol.

These results strongly suggest that amounts of alcohol far too small to give rise to recognizable signs of intoxication may none the less significantly impair driving ability. At the same time, the authors are properly cautious in generalizing from their findings to driving—and drinking—under conditions less austere than those of the laboratory. The effects of small doses of alcohol upon confidence, decision and judgment were assessed little, if at all, in the present series of experiments, and the range and extent of compensatory activities have still to be

defined with precision. None the less, this report deserves the most careful attention on the part of all concerned with the pressing problem of road safety.

Domestic Oil-heating

"Britain Turns to Oil Heat" is the title of an anonymous but significant contribution to the combined summer and autumn (1959) number of the *Esso Magazine*, house organ of the Esso Petroleum Co. Domestic heating by oil is increasing rapidly. Just after the War there were 5,000 houses with oil-fired central heating; in 1957 there were 16,000; and in 1958, 40,000. Similarly, portable oil heaters have increased in popularity from 2½ million to more than 10 million in the past five years. Perhaps the most interesting information in this article, especially in view of recent publicity given to fatal accidents with oil heaters, is quoted from a consumer's association. Ten different models were burned together in a room for several hours without creating odour. They were then knocked on their backs to see if they would spill burning oil; but in every case the flame either went out or returned to normal burning when the heater was set up again in correct position. Finally, the models were subjected to blasts of air to see whether flames would burn in a dangerous manner. In no case did anything catch fire, a remarkable result and tribute to the various heater designs involved.

Parametric Amplifier Diode

'EW97/1', a variable capacitance diode designed for use in parametric amplifiers at frequencies up to *S*-band, is now in production by the General Electric Co., Ltd. (Semiconductor Division). The Company claims that it is the first device with these qualities to be made available in the United Kingdom. The price is considerably lower than that of the units which previously had to be imported. The diode is suitable for use in radar and other communications systems. Designed for high power dissipation, it needs no elaborate precautions against surges. It is mounted in a coaxial structure for direct insertion into coaxial and wave-guide circuits and it has the very low series inductance of 0·5 μH. A reverse polarity version ('EW98/1') is also available. Because of its very low forward impedance and very high reverse impedance, the device can be used as a micro-wave switch. Another application is as a frequency multiplier—an important aid towards the future design of micro-wave receivers based entirely on solid-state devices.

Palæolithic Remains at Willendorf

Every prehistorian knows of the Venus of Willendorf, and some of them know that the figurine comes from a site near the village of the same name which lies on the left bank of the Danube between Melk and Krems, upstream from Vienna. The figurine itself is made of a fine-grained oolite, is some 10 cm. in height, and is highly conventionalized. It can be dated to a late palæolithic epoch. But up to now very little detail has been generally known about the find, the site itself, and the associated industry. Now three fascicules of the Prehistoric Commission of the Austrian Academy of Science have been devoted to these matters (Mitteilungen der Prähistorischen Kommission der Österreichischen Akademie der Wissenschaften. VIII und IX Band: Willendorf in der Wachau: Monographie der Paläolith-Fundstellen I–VII. 1 Teil: Text. Pp. v+219. 2 Teil: Inventar. Pp. 79. 3 Teil: Abbildungen. Abb. 124. (Wien: Österreichische Akademie der Wissenschaften, 1959)). At Willendorf there are a number of loess sites which have yielded upper palæolithic industries; the famous figurine came from site 2. The first fascicule includes a full account of the sites and the various excavations that have taken place there; Part 2 is a catalogue of all the finds of stone and bone tools that have been unearthed; Part 3 is entirely taken up with pictures of the more important tools, which enable datings for the various levels to be suggested. A work of this nature is long overdue. Now at last prehistorians have the full facts connected with one of the more important works of art of late palæolithic man that has survived.

The Transvaal Museum

The annual report of the Transvaal Museum, Pretoria, for the year ended March 31, 1959, once again directs attention to the desperate need for more accommodation. The Trustees consider that the people of South Africa have been unduly penalized in that large sections of the collections in both the natural sciences and history are steadily deteriorating owing to lack of storage and display space. Proposals for a separate and independent cultural history museum and an open-air historical museum are also being discussed at a high level with the Minister of Education. An entrance charge (1*s.* per head for adults but free for children under sixteen and recognized groups of students) has been made. The revenue is devoted exclusively to the improvement of the collections, and it is interesting to note that the decrease in attendances is not nearly so great as was expected.

Student Exchange

During the summer vacation of 1959 the number of students sent and received under the programme of the International Association for the Exchange of Students for Technical Experience of Great Britain increased to 854 students received, and 837 students sent; the corresponding figures for 1958 were 829 and 774, respectively. Some 366 British companies took part in the scheme. In April 1959 a general meeting of representatives of affiliated universities, colleges and companies was convened to consider the future organization of the Association, in Great Britain. It was decided to establish an independent council to control the Association, and the legal formalities are now proceeding. It is anticipated that the new Council of the Association will operate from September 1960. Greece has been accepted as a full member of the Association, and Poland and Tunisia have been admitted as associate member countries for one year. Further information about the Association can be obtained from J. Newby, superintendent of vacation studies, Imperial College of Science and Technology, London, S.W.7.

Scottish Field Studies Association

The Scottish Field Studies Association has announced its programme for the forthcoming season April–September. The courses will be based on the Garth Field Centre and the Isle of Ramsey, and accommodation fees will be up to 4½ guineas a week. Members of local scientific societies qualify for bursaries of £3 (for a course lasting a week) from a

fund made available by the Carnegie United Kingdom Trust. Further information can be obtained from the Scottish Field Studies Association, c/o Department of Botany, The University, Glasgow, W.2.

Symposium on Herbicides and the Soil

The British Weed Control Council has arranged a symposium on Herbicides and the Soil, which will be held in the Clarendon Laboratory, Parks Road, Oxford, on April 7. Four papers will be presented. The first will be by Prof. L. J. Audus (Bedford College, London) on "Microbiological Breakdown of Herbicides in Soils". Prof. W. Fletcher (West of Scotland Agricultural College, Glasgow) will speak on "The Effects of Herbicides on Soil Micro-Organisms", and Dr. G. S. Hartley (Chesterford Park Research Station) on "Physico-chemical Aspects of the Availability of Herbicides in Soils". The symposium will be concluded by Dr. Ir. W. van der Zweep (Wageningen), who will speak on "Persistence in the Soil of Some Important Herbicides". Further information can be obtained from G. R. Sagar, Unit of Experimental Agronomy, Department of Agriculture, University of Oxford.

Announcements

Dr. D. A. Senior, whose appointment to the newly created post of scientific attaché to the British Embassy in Moscow was announced in *Nature* of April 11, 1959, p. 1018, left London to take up his post on January 31. Dr. Senior has no specific technical assignment in Moscow, but will cover the broad field of science and technology. His aim is to promote good relations and understanding between the two countries in this field and to facilitate exchanges of information and people.

Dr. A. D. Macdonald, Leech professor of pharmacology in the University of Manchester, has been appointed Officier de l'Ordre de la Santé Publique by the French Minister of Health. Prof. Macdonald, one of the members of the Pharmaceutical Society's Council nominated by the Privy Council, has been for two years president of the British section of the Franco–British Pharmaceutical Commission, a body set up as a result of a suggestion made by Sir Winston Churchill that members of the same professions on each side of the Channel should get to know one another better.

Dr. A. W. Meschkat, of Hamburg, has been appointed as Food and Agriculture Organization regional fisheries officer for Africa. He will assist governments to develop fish production of the seas off East and West Africa and of the lakes and rivers of Central Africa.

Mr. A. L. Jewell, assistant curator of Heslemere Museum, has been appointed to a newly created post of exhibitions officer at the Royal Botanic Gardens at Kew. Mr. Jewell will be joining the staff of the Keeper of Museums at Kew and his special concern will be to re-display existing exhibits.

Dr. R. H. Hedley, a senior scientific officer in the Department of Zoology, British Museum (Natural History), has been awarded the 1960 New Zealand National Research Fellowship and will work on some aspects of the biology and systematics of marine allogromoid Foraminifera (Protozoa) living in New Zealand coastal waters.

The Corday-Morgan Award, consisting of a silver medal and a monetary prize of 200 guineas, is made annually to a chemist of British nationality who, in the judgment of the Council of the Chemical Society, has published during the year in question the most meritorious contribution to experimental chemistry, and who has not, at the date of publication, attained the age of thirty-six years. Copies of the rules governing the Award may be obtained from the General Secretary of the Society. Applications or recommendations in respect of the Award for the year 1959 must be received not later than December 31, 1960, and applications for the Award for 1960 are due before the end of 1961.

The sixty-fifth annual congress of the South-Eastern Union of Scientific Societies will be held at Ipswich during April 22–25. Further information can be obtained from Mr. Frank Edwards, 53 The Drive, Shoreham-by-Sea, Sussex.

The annual spring conference of the Institute of Metal Finishing will be held in the Grand Hotel, Scarborough, during April 26–30. Further information can be obtained from the Honorary Secretary, Institute of Metal Finishing, 32 Great Ormond Street, London, W.C.1.

The spring conference of the X-Ray Analysis Group of the Institute of Physics will be held in the main Chemistry Lecture Theatre, University of Reading, during April 8–9. The subject will be "The Borders of X-ray Analysis". Further information can be obtained from Dr. P. T. Davies, "Shell" Research, Ltd., Thornton Research Centre, P.O. Box 1, Chester.

A symposium, sponsored by the Office of Ordnance Research U.S. Army, will be held in the Inorganic Chemistry Laboratory, Oxford, during April 5–6, on Plastic Crystals and Rotation in the Solid State. Further details can be obtained from L. A. K. Staveley, Inorganic Chemistry Laboratory, South Parks Road, Oxford.

The Ergonomics Research Society is holding its annual conference at the University of Cambridge during March 28–31. The programme will include two sessions on "Ergonomics in the Armed Forces", a session on "Ergonomics in the Netherlands", and a symposium on "Factors in Prolonged Work, especially Inspection". Further information can be obtained from the conference secretary, Dr. S. Griew, University of Bristol, Department of Psychology, 22 Berkeley Square, Bristol 8.

The Turkish Bibliography of Articles appearing in Turkish Periodicals for January–March 1959 is provided with a foreword in French as well as Turkish, and the classification, too, is now given in French as well as in Turkish. Titles of the periodicals covered are listed in French and Turkish, and each entry is provided with a French translation of the title; titles are arranged according to the Dewey Decimal Classification up to the first two or three figures only.

A research scholarship in the use of light alloys in structural engineering is being offered by the Institution of Structural Engineers in collaboration with the Aluminium Development Association. The duration of the scholarship will be for two years and the value £600 per annum. The award is made every three years as from October 1. Further information can be obtained from the Secretary of the Institution of Structural Engineers. Completed application forms should be sent to reach the Secretary by March 31.

INDUSTRIAL ARCHÆOLOGY

THE conference held at the London School of Hygiene and Tropical Medicine on December 12 was the first event organized by the recently formed Research Committee on Industrial Archæology of the Council for British Archæology. The large attendance of some 180 people was very encouraging, and confirms the Council in its belief that considerable interest exists as well as concern about the fate of industrial monuments.

Dr. J. N. L. Myres, president of the Council, took the chair, and the conference opened with the reading of a message from the Minister of Works. The first paper was by Mr. M. M. Rix, staff tutor in architectural history in the University of Birmingham, on "Industrial Archæology as illustrated in the West Midlands". This area is a particularly rich field, and Mr. Rix described many fine examples such as Ironbridge and Coalbrookdale, Telford's canal aqueducts, and the earliest existing iron-framed building, a former flax-spinning mill at Shrewsbury.

The second paper, by Mr. J. M. Palmer, was on "The Stamford Canal: a Seventeenth Century Navigation". His chief purpose was to show how the history of a canal, the very site of which can only with difficulty be identified, may be reconstructed by a thorough search of national and local records. The paper was introduced by Mr. Maurice Berrill, honorary secretary of the Railway and Canal Historical Society.

The afternoon session began with a paper by Prof. A. W. Skempton, of the Imperial College of Science and Technology, London, on "Structural Development of the First Iron-framed Textile Mills" He showed how iron-framing was originally developed because of the danger of fire in early factory buildings. The development was one of very great importance as it culminated in the steel-frame buildings of the first examples of modern architecture designed by Louis H. Sullivan in Chicago towards the end of last century. Prof. Skempton showed how skilfully he had combined study of actual buildings and documentary records to establish the sequence of mills in Derbyshire and at Shrewsbury and Salford.

The remainder of the afternoon session was devoted to three short papers. The first was a brief note by Mr. C. W. Phillips, read in his absence owing to illness, on the Ordnance Survey in relation to the recording of industrial archæology. Mr. Phillips, who is archæology officer to the Ordnance Survey, pointed out that surveying and recording are being extended to include early industrial remains. He also made it clear that the records compiled by the Ordnance Survey on such sites will be available to research workers. Dr. P. M. G. Eden, of the Royal Commission on Ancient Monuments, gave a most practical short address on the technique of recording industrial monuments. He encouraged amateur field groups by emphasizing that preliminary work in recording often serves as a basis for specialist studies. Mr. J. M. Richards, editor of the *Architectural Review*, read the final paper on "Visual Aspects of the Subject and the Æsthetic and Landscape Value of Early Industrial Monuments", in which he distinguished between the architectural quality of industrial buildings and their part in the landscape in so far as it was a creation of man. Mr. Richards's thesis that the best of our early industrial buildings mark the beginning of the functional tradition in architecture is already well known.

In the discussions which were held after the papers during both morning and afternoon sessions a keen concern could be observed with how the recording of industrial remains might be carried out and appropriate examples preserved. The need for the co-ordination of the activities of the different societies working in the field of industrial archæology was emphasized, as was the necessity for an informed public opinion which could bring pressure to bear on the appropriate authorities. It was even suggested that the Royal Commission on Historical Monuments should appoint additional staff to deal with the survey of industrial remains. Hopeful developments were referred to such as the action of Allied Ironfounders in clearing the site of the old Coalbrookdale ironworks, the first scientific excavation of an industrial site by the British Museum at the Longton Hall porcelain factory, and the appointment of an archæological officer in the Staffordshire County Planning Department.

The conference closed with a summary by Mr. Maurice Barley, secretary of the Council for British Archæology, at the conclusion of which he read a draft resolution. A discussion followed in which the chief points made were the necessity to interest industry in the work of record and preservation and to emphasize the educational importance of industrial archæology when so much was being heard of the need for increased technical and scientific training.

The resolution as finally passed declared that the conference was deeply impressed by the need for formulating a policy for recording and, where necessary, preserving early industrial monuments. The Research Committee on Industrial Archæology was further instructed by the resolution to find opportunities to discuss with central and local authorities, as well as with industry and unofficial bodies, the question of record and preservation.

The Research Committee proposed as a first step to prepare a handbook of industrial archæology which would serve as a guide to societies and individual research workers anxious to carry out surveys of industrial remains. Plans are now being made to initiate a pilot survey either of a region or of a particular industry. It is also hoped to hold regional conferences, and as soon as possible to organize courses at which some training in recording and interpreting industrial sites can be given.

The immediate task of the Committee is to establish closer contact between the individual research workers and societies which have been working in different parts of the field covered by industrial archæology and to attempt to direct their efforts towards the creation of a single discipline. The work of the Committee, if successful, will go a long way towards establishing the study of the history of

technology on a more respectable footing in Britain as well as supplementing the work of economic and social historians. Much depends on the degree of interest which can be aroused among scientists and technologists, without whose assistance it will be virtually impossible to go on to specialized surveys of particular industries. The Committee already includes archæologists, historians, architects, geologists and technologists, but would warmly welcome the co-operation of more people with specialized knowledge of mining, quarrying, textiles, metallurgy, chemicals, civil and mechanical engineering or any of the other innumerable subjects in this vast field of industrial archæology. E. R. R. Green

NINTH CANADIAN HIGH POLYMER FORUM

THE ninth Canadian High Polymer Forum, held at the Guild Inn, Toronto, during October 26–28, was attended by 142 chemists from Great Britain, the United States and Canada. The chairman was M. H. Jones (Ontario Research Foundation) and the session chairmen were S. Bywater (National Research Council), H. H. G. Jellinek (Essex College), M. Rinfret (University of Montreal) and G. Olah (Dow of Canada).

At the business meeting on October 26 the officers for the tenth Forum were elected: *chairman*, L. A. McLeod, Polymer Corporation; *programme chairman*, K. E. Russell, Queen's University, Kingston, Ontario; *secretary-treasurer*, D. A. I. Goring, Pulp and Paper Research Institute.

At the banquet on October 27, the guest speaker, C. H. Bamford, of Courtaulds, Maidenhead, spoke on "Patterns in Reactions and Polymers". He said that detailed information is now available concerning transfer reactions of polymer radicals with a variety of substrates. For a hydrocarbon substrate such as ethylbenzene, the rate constants for the hydrogen abstraction process involving a series of polymer radicals are fairly accurately proportional to the rate constants for the corresponding reactions with toluene. In these reactions with hydrocarbon substrates, polar factors are very small. With ferric chloride, butyl mercaptan or carbon tetrabromide as substrates, a logarithmic plot of rate constants for the transfer reaction against rate constants for the corresponding reaction with toluene gives a number of scattered points. The pattern of points is, however, very much the same in all three cases. With triethylamine as substrate an 'inverse' pattern is obtained. Patterns of the first type are obtained in addition reactions involving the same polymer radicals and a number of vinyl monomers.

The observed patterns can be interpreted in terms of polar effects, the rate constant depending considerably on the extent to which the substituent in the radical is electron-withdrawing or electron-releasing. From a quantitative treatment, Dr. Bamford concluded that it is possible to express the rate constant for the transfer reaction of a radical with a given substrate in terms of the rate constant for transfer with toluene and the Hammett σ constant for the radical. Predictions based on this quantitative theory are in excellent agreement with experiment.

The main sessions began with a paper by J. K. N. Jones (Queen's University) on "Some Problems in Polysaccharide Chemistry". In pointing out some of the difficulties involved in complete structural determinations of polysaccharides, he said that it is not always possible to decide whether traces of sugars occurring with the main hydrolysis products of polysaccharides were part of the original macromolecule. Degrees of branching can be readily obtained using the Haworth methylation technique, but frequently it is almost impossible to achieve 100 per cent methylation of a polysaccharide. The major problem in this field is to imitate the action of enzymes on sugars and sugar derivatives to produce polymers similar to those found in plants and animals.

B. L. Funt and F. D. Williams (University of Manitoba) in their paper on "Retardation and Inhibition of Methyl Methacrylate Polymerization" described investigations of the effect of benzoquinone on methyl methacrylate polymerization using quinone and initiator labelled with carbon-14. They observed a transition from retardation to inhibition at a critical concentration of benzoquinone. The Monday morning session closed with a short colour film on polymer interactions made available by W. F. Busse, Du Pont Co., Wilmington.

The first in a series of papers on polymer degradation was given by H. A. Kraessig and J. Neal (Industrial Cellulose Research), who discussed "The Degradation of Cellulose by Megavolt Electrons". They showed that at low dose-rates the number of chemical bonds broken is a linear function of the dose, and the sensitive volume corresponding to cleavage of a single bond is close to the volume of a monomer unit. Experiments on wet cellulose indicate that water has a considerable protective action. H. H. G. Jellinek (Essex College) and W. A. Schlueter described work performed at the University of Cincinatti on "The Photodegradation of Polyacrylonitrile in Solution", using light of wave-length 2537 Å. The rate of degradation *in vacuo* is proportional to the light intensity and the number of broken bonds is less than 10^{-3} per quantum absorbed. W. C. Schneider (American Cyanamid) spoke on "The Thermal Stability of Polyacrylonitrile". At 240° in the absence of oxygen he observed that the polymer breaks down very rapidly giving a complex mixture of products, but in the presence of oxygen a more controlled reaction gives water, ammonia and hydrogen cyanide as the only volatile products. J. R. Schaefgen (Du Pont) presented a paper on "The Thermal Degradation of Poly-*p*-xylylene". The rate of degradation was measured in a chlorinated aromatic solvent in the range 285–321°. Degradation is random, and the activation energy is 58 kcal./mole. Anthracene decreased the rate of degradation, but common transfer agents are inactive.

R. J. Orr (Polymer Corporation) presented a paper on "Thermochemical Aspects of Free Radical Butadiene-Styrene Copolymerization". A treatment of the thermodynamics of copolymerization has been devised which can be applied to high-conversion material. The sum of the entropy changes for the two heteropolymerization steps was found to be

about 50 entropy units/mole assuming that the residual entropy contributed by the glassy state is zero.

C. Booth and L. R. Beason (Shell Chemical) gave a paper on "Statistical Treatment of Polymer Fractionation Data". A styrene-butadiene copolymer was fractionated and the fractionation data subjected to a simple binomial analysis. The resulting distribution of molecular weight was in good agreement with that calculated from the kinetics of the emulsion system. J. A. Manson, W. W. Graessley and L. M. Hobbs (Air Reduction Co.) described "The Determination of the Breadth of Molecular Weight Distribution in Polyethylene by an Irradiation Technique". Samples of high-pressure and low-pressure polyethylene were irradiated using a cobalt-60 source and were analysed for soluble and gel fractions. From the results it is possible to calculate weight and number average molecular weights of the original polyethylene samples.

A. Rezanowich and D. A. I. Goring (Pulp and Paper Research Institute) have investigated "The Polyelectrolyte Properties of a Lignin Sulphonate Microgel". Their measurements of the polyelectrolyte expansion of fractions of sodium lignin sulphonate indicate a microgel structure for the macromolecule. They developed a theory assuming that the microgel structure has free charges only on the surface and showed that it agreed fairly well with experiment.

D. J. Worsfold and S. Bywater (National Research Council) spoke on "Some Properties of Poly-α-methylstyrene produced by Anionic Polymerization". They have made a thorough molecular weight analysis of poly-α-methylstyrene samples produced using sodium naphthenide as catalyst. One important result is the intrinsic viscosity–molecular weight relationship for polymer samples of very sharp distribution.

M. Senez and H. Daoust (University of Montreal), in their paper on "Heat Parameters for Poly*iso*-butylene Solutions", compared heat parameters determined for the poly*iso*butylene–chlorobenzene system by calorimetry and by the viscosity method of Fox and Flory. The results fit the Fox and Flory treatment of viscosity data.

W. Heller and M. Nakagaki (Wayne State University), in "The Exact Theory of the Scanning Method for determining Particle Sizes from Light Scattering", gave accurate calculations of the angular positions of maxima and minima for non-absorbing spheres for the large relative refractive index of 1·20. The results for other relative refractive indexes can now be calculated fairly readily.

T. Gillespie (Dow Chemical) presented papers on "The Limited Flocculation of a Colloidal System by a Water Soluble Polymer" and "The Rheology of a Polystyrene Latex thickened with Methylcellulose". His results on the flocculation of styrene–butadiene latex by methylcellulose indicate that the stabilization of a hydrophobic colloid by a hydrophilic colloid is due to changes in the balance of the flocculation and deflocculation processes. Methylcellulose thickens a polystyrene latex by causing a reversible partial flocculation.

A. Novak and E. Whalley (National Research Council) presented data on "The Infra-red Spectrum of Polyformaldehyde" and showed that these data could be interpreted on the assumption of a helical model for the polymer.

E. H. Immergut, G. Kollmann and A. Malatesta (Dunlop Research Centre) reported results on "The Cationic Copolymerization of Propylene and Isoprene". They prepared soluble copolymers under carefully controlled conditions using aluminium chloride as catalyst at −78° (molecular weight range 4,000–10,000). Reactivity ratios for propylene and isoprene are approximately 0·23 and 0·5. M. H. Jones, U. Martius and M. P. Thorne (Ontario Research Foundation) discussed "The Polymerization of 1-Butene by Metal Alkyl–Titanium Halide Catalysts". They reported the results of chemical and X-ray analyses of the complex catalysts produced by the interaction of aluminium triisobutyl or lithium *n*-butyl with titanium trichloride or tetrachloride. Kinetic results for the polymerization of butene-1 using aluminium triisobutyl–titanium trichloride were given; the products were of very high molecular weight (intrinsic viscosity between 5 and 6).

C. H. Bamford, in a paper on "Termination by Primary Radicals in Vinyl Polymerization", said that when the initiator concentration is high, a plot of rate of polymerization of styrene versus monomer concentration is curved. This can be quantitatively accounted for by assuming termination of some growing polymer radicals by primary radicals from the initiator. The velocity constant for primary radical termination is about sixty times that for mutual termination. The interaction of unlike radicals was also discussed by C. Sivertz and Y. Ebisuzaki (University of Western Ontario) in a paper on "The Measurement of the Cross-Termination Velocity Constants for Picrylhydrazyl and Alkyl Radicals". They studied the thermal decomposition of azobisisobutyronitrile at such low concentrations that the combination of free cyano-alkyl radicals competed with the reaction with diphenylpicrylhydrazyl. The relationship between the two velocity constants was derived.

L. E. Coleman and J. F. Bork (The Lubrizol Corporation) spoke on "The Reactivity Ratios of N-Vinyl Oxazolidone and N-Vinyl Pyrrolidone with Vinyl Monomers". N-Vinyl oxazolidone copolymerizes well with vinyl chloride and vinyl acetate but not with styrene and methyl methacrylate; N-vinyl pyrrolidone is more reactive than N-vinyl oxazolidone. W. E. Walles, W. F. Tousignant and T. Houtman (Dow Chemical) have studied "Poly-N-vinyl, 5-Methyl 2-Oxazolidone (PVOM) a New Complexing Polymer". PVOM of molecular weight 150,000 is soluble in water below 40° and insoluble at higher temperatures. This behaviour is explained in terms of a change from a structure which presents largely hydrophilic groups to the solvent to one which is almost entirely hydrophobic.

R. J. Ceresa and F. H. Cotton (National College of Rubber Technology, London), in presenting a paper on "The Mechanico-Chemical Modification of High Polymers", said that cold mastication of elastomers in the presence of 0·1 per cent aluminium isopropoxide eventually leads to gels; under similar conditions a mixture of polyvinyl acetate and polyethylene may give a fair yield of block copolymer.

R. J. Richardson (Atomic Energy of Canada) spoke on "Radiation Grafting of High Polymers". Nylon tenting fabric was irradiated with gamma-rays in the presence of styrene to give polystyrene grafts largely on the surface of the nylon, with a resultant improvement in its weathering properties. Irradiation of nylon and terylene in the presence of acrylonitrile and vinyl pyrrolidone gave a slight improvement in dyeing response.

J. R. Tichy (Maine Medical Center), in his paper on "The Polymerization of Phosphorus Pentachloride

and Urea", presented analytical data on the products of this complex polymerization. In the last paper presented, R. W. Lenz and W. K. Carrington (Dow Chemical) discussed "The Preparation of Phenylene Sulphide Polymers by the Macallum Polymerization". The reaction of *p*-dichlorbenzene with sulphur and sodium carbonate at 300–350° to give a high molecular weight phenylene sulphide polymer probably proceeds partly by a direct attack of sulphur diradicals on the dihalide and partly by attack of sodium sulphide formed by reaction of sulphur with sodium carbonate.

K. E. Russell

DIELECTRIC DEVICES

An informal residential conference on dielectric devices was held in the Electrical Engineering Department of the University of Birmingham during September 14–17, 1959, inclusive, and was attended by representatives from universities, Government establishments and industry. The aims of the conference were to give those participating a broad overall picture of this sector of solid-state physical electronics, to discuss present trends and new ideas connected with the investigation and exploitation of dielectrics, and to stimulate research on dielectric materials and devices. In an attempt to achieve these aims each session was opened with an invited general paper which reviewed physical principles and assessed practical progress in exploitation; each session then continued with shorter papers describing current research on the properties of materials and the mechanisms of devices.

The first paper of the conference opened the session on masers and parametric amplifiers. This was given by I. M. Ross (Services Electronics Research Laboratories, Harlow), who reviewed the mechanisms of these devices and compared their more important characteristics such as gain bandwidth products and noise figures. J. C. Walling (Mullard Research Laboratories, Salfords) then described the paramagnetic resonance characteristics of chromium-doped potassium cobalticyanide and the advantages of maser operation using 'push–pull' and 'push–push' pumping. Experimental realization of both types of double pumping had been obtained in a cavity maser at a signal frequency of 2,900 Mc./s. with respective root-gain bandwidth products of 12 and 19 Mc./s. in the two cases.

In the following paper, by B. Bölger, N. J. Robinson and J. Ubbink (Philips, Eindhoven), read by J. Ubbink, the characteristics of a 1,420 Mc./s. maser were described. A three-level maser using potassium cobalticyanide at 1·4° K. with a pump frequency of 3,850 Mc./s. and a signal frequency of 1,420 Mc./s. had been constructed. A root-gain bandwidth product of 2·7 Mc./s. with a limiting power of 2×10^{-7} W. had been obtained. The final paper of this session dealt with parametric amplification and was given by L. E. Cross (Electrical Research Association, Leatherhead), who considered the use of a ferroelectric material above its Curie temperature as a possible variable reactance for this purpose. The electro-mechanical effects in ferro-electrics were briefly discussed and saturation functions derived for barium titanate and glycine sulphate. Measurements showed that glycine sulphate could not be used at 500 Mc./s. due to enhanced dielectric losses near the Curie temperature.

The second session was opened by G. F. J. Garlick (University of Hull), who reviewed the physical mechanisms of photoconductivity and luminescence. H. G. Lubszynski (E.M.I., Hayes) then explained how the use of an electron beam for making contact to a semi-conductor offers advantages in the case of near insulators because it allows thin films of large cross-sectional area to be used with less danger of shorting. Organic luminescence and the scintillation counter formed the subjects of the next two papers. In the first of these, J. B. Birks (University of Manchester) discussed the fast and slow components of scintillations in organic materials. The former was attributed to direct singlet-state excitation, was subject to primary quenching, and hence depended on the nature of the particle. The latter was attributed to ion recombination leading to excitation of metastable triplet states, was less subject to primary quenching, and was largely independent of the nature of the particle. P. E. Gibbons and D. C. Northrop (Services Electronics Research Laboratories, Baldock) then described experiments on the long-lived decay components of anthracene scintillations showing that the characteristic times are independent of exciting particles and temperature. These and other experiments on impure anthracene show that these components probably derive from some co-operative lattice property and not a molecular one.

The opening paper of the third session was given by G. Diemer (Philips, Eindhoven), who reviewed present and potential applications of luminescence and photoconductivity in power amplification. The first research paper of the session was read by P. K. Weimer for E. E. Loebner (R.C.A., Princeton) and explained how it should be possible to escape the gain-bandwidth limitations of currently available luminescence amplifiers by using luminor elements themselves capable of modulation and amplification. The second research paper was given by J. Woods (G.E.C., Wembley), who described experiments showing that cadmium sulphide crystals doped with 1–2 per cent copper are *p*-type. Measurements of electrical conductivity, σ, Hall coefficient, R, and thermoelectric power, α, had been made from 95° K. to 380° K., and suggested transport via impurity-levels. At 300° K. it was found for $\sigma = 0{\cdot}18$ ohm^{-1} cm.$^{-1}$ that $p = 1/Re = 5{\cdot}6 \times 10^{16}$ cm.$^{-3}$, $\mu = R\sigma = 20$ cm.^{2} volt^{-1} sec.$^{-1}$, and $\alpha = 22$ μV./°C.

Space-charge-limited current in dielectric crystals formed the topic for the fourth session. The opening paper of this session was given by G. T. Wright (University of Birmingham) and reviewed the mechanisms of space-charge-limited current in dielectrics and, on the basis of a simplified theory and available experimental data, assessed tentatively potential fields of application of space-charge-limited dielectric devices. In a short following paper, A. A. Kayali (University of Birmingham) described measurements of the temperature dependence of forward current of a number of space-charge-limited cadmium sulphide dielectric diodes. In diodes with a small trap density the current increased slowly as the temperature was lowered from 400° K. to 90° K. due to the increase of electron mobility at

the lower temperatures; above room temperature there was little variation of characteristics. In most cases the square-law dependence of current upon voltage was obeyed over this whole temperature-range. High-speed switching characteristics of the diodes were described in a paper by A. M. Conning (University of Birmingham). For both 'switch-on' and 'switch-off' operation steady-state conditions were reached in a time less than 3 mμsec., the response time of the measuring equipment; charge storage effects in the diodes were undetectable. The final paper of this session was given by G. T. Wright and discussed the design of a proposed amplifying dielectric triode, which should possess a high input resistance, a large gain-bandwidth product, and be relatively insensitive to temperature changes. Calculations showed that the presence of shallow trapping levels ($< 0{\cdot}30$ eV.) should result in the mutual conductance at high frequencies (> 10 Mc./s.) being many times greater than at audio frequencies.

The opening paper of the fifth session was given by W. J. Merz (R.C.A., Zurich) on the subject of ferro-electricity. Present ideas of basic mechanisms in 'soft' and 'hard' ferro-electrics were reviewed and outstanding problems such as nucleation and losses above the Curie point considered. In the following paper, by K. W. Plessner (British Dielectric Research, London) and R. West (United Insulator Division, T.C.C., Chessington), the influence of the chemical composition of high permittivity ceramics upon their electrical properties was discussed. The application of chemical processes on an industrial scale was then considered. J. H. Bruce and J. R. Balmer (Radio Research Establishment, Malvern) then discussed the need for thin-film capacitors and the suitability of an evaporation method for producing these. Experimental techniques and results for silicon monoxide capacitors were described. The last paper of the session was given by R. C. Kell (G.E.C., Wembley), who discussed piezoelectric ceramics. It had been found that niobate ceramics retained their piezoelectric properties at temperatures considerably higher than ceramics based on barium titanate and that their properties showed less variation with temperature. In particular, sodium–cadmium and lead–barium niobates were more suitable than barium titanate ceramics for use in vibration detectors, ultrasonic generators, and resonators for filter networks.

The final session of the conference included contributions from S. Duinker (Philips, Eindhoven) on a square-loop ferrite device for the fast scanning of electroluminescent cross-bar systems; from D. W. G. Ballentyne (Siemens Ediswan, Harlow) on the possible explanation of electroluminescence as a disorder phenomenon; from R. M. Glaister (G. V. Planar, Ltd., Sunbury) on relaxation polarization dielectrics; from E. A. D. White (G.E.C., Wembley) on the effects of additives on the properties of barium titanate ceramics; from J. C. Burfoot (Queen Mary College, London), who discussed switching in ferroelectrics; from Mr. F. H. Stieltjes (Philips, Eindhoven), who discussed losses in ferro-electrics with particular reference to their use in parametric amplifiers; and G. T. Wright on the trap content of dielectrics with particular reference to the characteristics of dielectric diodes.

The conference emphasized that very great potentialities exist for the exploitation of dielectrics in devices although only limited practical progress has yet been made. There is no doubt, however, that the number and diversity of outstanding problems make this a most attractive field for both fundamental and applied research.

G. T. WRIGHT

THE NATIONAL RESEARCH DEVELOPMENT CORPORATION OF GREAT BRITAIN

IN view of the stress laid on the work of the National Research Development Corporation by Prof. C. F. Carter and Prof. B. R. Williams in "Science in Industry" and of the interest in the Corporation which Lord Hailsham has already shown, the Corporation's annual report for the year July 1, 1958–June 30, 1959, will doubtless be closely examined by scientists and technologists as well as industrialists (National Research Development Corporation. Report and Statement of Accounts for the year 1st July, 1958, to 30th June, 1959. Pp. ii+22. London: H.M. Stationery Office, 1959. 1*s.* 3*d.* net). This year's report is limited to a factual account of the year's work, but the report comments on the greater attention now paid to the Corporation's work by the scientist and industry as well as by the general public, and confidence is expressed that the Corporation's unique experience will enable it to play an ever increasing part in the application of scientific ideas to industry. Revenue from inventions rose to £189,761, and there was also a non-recurring item of £92,978 from sale of patent rights. Government departments and research councils assigned patent rights in 119 cases, compared with 86 in 1958–59, 59 of the total of 187 coming from universities and 5 from industrial research associations, compared with 49 and 1, respectively, out of 147 in 1957–58. Of 681 inventions communicated to the Corporation during the year, compared with 612 the previous year, 287 were from Government departments and research councils, 27 from Commonwealth official organizations, 60 from universities, 8 from industrial research associations and 296 from private firms and individuals, 263 in the United Kingdom. Holdings of British and foreign patent applications totalled 2,794, including 419 United Kingdom patent applications and 580 granted patents, 820 overseas applications and 975 granted patents.

Among new projects initiated during the year or reaching a stage suitable for report are Dr. I. E. Bush's automatic apparatus for chemical treatment and scanning of chromatograms, which has speeded up procedure considerably; the development of the new antibiotics called the cephalosporins, particularly cephalosporin *C*, which is resistant to destruction by penicillinase; Prof. E. C. Cherry's television compression system using a variable scanning velocity so adjusted as to keep the transmitted frequencies within a desired bandwidth. An experimental system based on a 30-line picture has been constructed, and a further experimental system operating on 405 lines is being developed. A contribution has been made towards the cost of equipment to assess a proposal for an improved rolling mill, using rolls supported in

hydrostatic bearings, and the Council decided in September 1958 to sponsor the development of Mr. C. S. Cockerell's inventions relating to "Hovercraft", and has formed a subsidiary company, Hovercraft Development, Ltd., to be responsible for its interest in this project. Financial assistance is being provided to complete the development of equipment capable of continuously processing hides and so giving increased capacity allied to smooth-running production and control. As a result of arrangements made by the Corporation to develop and exploit a new type of ditch cleaning media, a British manufacturer is building five prototypes, and the test results of the National Physical Laboratory on the robust and reasonably effective stabilizer designed in 1956 have now been checked on a full-scale ship.

Reference is also made to further developments in a process for producing acetylene by partial combustion of methane, to satisfactory negotiations for financial support of the computer-controlled machine tool project to be taken over by more appropriate organizations; the completion of a further design study permitting detailed assessment of the economic advantage of Fanshawe's oil-well drilling rig, and of the initial three-year programme of work on the ion-exchange membrane project, under which a process has been developed for continuous electrochromatography. Considerable further development will be required before the hydrogen–oxygen fuel cell can be launched on a commercial basis. New licensing arrangements were set up with a leading ice-cream manufacturer, who is now in production for the project for a freezing mill after treatment with ultra-sonic waves and pouring into waxed paper containers, and the process appears to offer prospects in the Middle East. Following successful testing and demonstration of the prototype flexible container for transporting oil, seven others have been ordered for use in different parts of the world.

SOLAR STILLS IN IRAQ

By Dr. A. V. BRANCKER
College of Science, University of Baghdad

EXPERIMENTS with solar stills and related units have been in progress at the College of Science, Baghdad, to provide fresh water for Bedouin communities, and to investigate the concentration of natural to heavy water.

Several designs of solar still were tested. Fig. 1 shows a still with a hemispherical 'Perspex' canopy. The base flange was held by screw clips on a gasket in a circular water channel. The complete unit included a flat-plate collector used as a preheater to increase the output of distilled water. The hemispherical still and a prismatic type with a glass canopy have been in continuous operation without maintenance since 1956. Only recently have fine superficial cracks appeared in the 'Perspex'. In other respects these stills, of essentially simple design, have been satisfactory. Curves of water yield versus time and temperature versus time curves for the hemispherical 'Perspex' and prismatic glass stills, with no preheating, are plotted in Fig. 2. The effect of dropwise condensation on the 'Perspex' unit and back reflexion is shown by the relative positions of the curves. The total water output and the dimensions of the stills are given in Table 1.

Table 1

Solar still	Depth of water	Yield of water (litres/sq. m./day)
Hemispherical canopy, radius 1·5 ft.	¼ in.	2·5
Prismatic canopy, 6·0 ft. × 2·2 ft.	¼ in.	3·6

On the basis of 3·60 litres or 0·79 gal. per square metre per day, the output, for a coverage of 1 acre, would be some 3,200 U.K. gal./day. Similar results were obtained by Lof[1] at 0·69–1·07 gal./sq. metre/day. In alternative units, the amount of water from a solar still is approximately 1 lb./sq. ft./day.

In addition to providing freshwater for small communities, in remote areas, another application is being considered. Thus, natural water contains 1 part of heavy water in 6–7,000 parts; therefore, very large quantities of water have to be vaporized or processed at heavy fuel costs. The relative volatility of heavy and ordinary water increases with decreasing temperature; this suggests the possibility of using solar evaporation and fractionation, which can proceed at relatively low temperatures and no fuel costs. One method of investigation is based on the flat-plate solar heater shown in Fig. 1, from

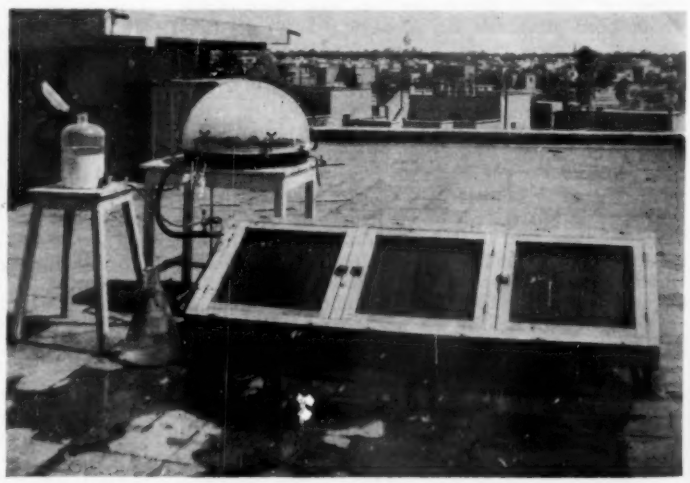


Fig. 1

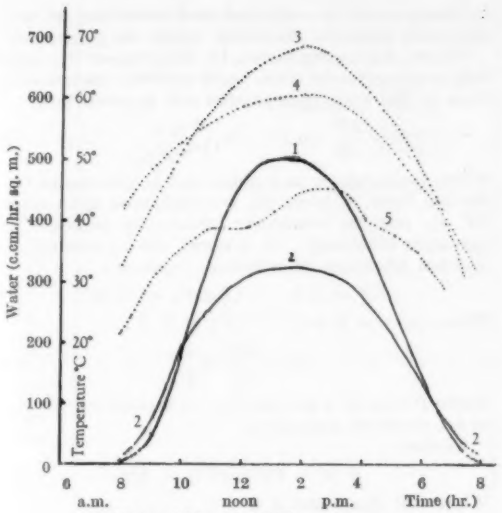


Fig. 2

which steam can be obtained. An alternative method is a solar-heated counter-current air–water stripping system. Using a packed tower, water is condensed from hot exit air at saturation humidity. It is not suggested that by solar evaporation methods a full recovery of heavy water is possible, but some preliminary concentration may be obtained for more conventional processing. Again, very large quantities of water would have to be evaporated, but it is precisely this condition which would be necessary in large-scale solar demineralization of brackish water. The objective, therefore, if possible, is to combine two needs.

The physics of evaporation in solar stills is related to the more complex problem encountered in studies of atmospheric evaporation, for which many equations have been derived. It is only possible to outline some methods which can be used. In Table 2, for example, is given a known comparison of heat and mass transfer equations using dimensionless groups.

Table 2

Heat transfer (1) Surface conditions	Mass transfer (1) Equimolecular counter-diffusion
$q = h\Delta T$	$N = k_D \Delta P/RT$
$q = -k\ \delta T/\delta x$	$N = -(D_a/RT)\ \delta P/\delta x$
$\theta = T/\Delta T$	$B = P/\Delta P$
$x^1 = x/L$	$x^1 = x/L$
$hL/k = \delta\theta/\delta x^1$	$h_D L/D_a = \delta\beta/\delta x^1$
$\theta = f(x^1, Re, Pr)$	$\beta = f(x^1, Re, Sc)$
$hL/k = f(Re, \nu/\alpha)$	$h_D L/D_a = f(Re, \nu/D_a)$
(2) Energy equation	**(2) Continuity equation**
$\rho\ DH/Dt - DP/Dt = Jk\nabla^2 T$	$DC/Dt = \mathbf{u}\nabla C + \delta C/\delta t = D_a\nabla^2 C$
$t^1 = vt/L$	$t^1 = vt/L$
$P^1 = P/\rho v^2$	$C^1 = C/\rho$
$H^1 = H/JC_p\Delta T$	$\mathbf{u}^1 = \mathbf{u}/v \ldots .$
$DH^1/Dt^1 - \frac{v^2}{JC_p\Delta T} DP^1/Dt^1 = \frac{\alpha}{vL}\nabla^2\theta^1$	$\delta C^1/\delta t^1 + \mathbf{u}^1\nabla C^1 = \frac{D_a}{vL}\nabla^2 C^1$
Geometrically similar systems	
$qL/k\Delta T = f\left(Re, Pr, \frac{v^2}{JC\Delta T}\right)$	$NL/D_a\Delta C = f(Re, Sc)$

The enthalpy balance in B.T.U. for a solar still of area A containing W lb. of brackish water of enthalpy and G lb. of an air–water vapour mixture of enthalpy H_a is given by:

$$WH_w + GH_a = (I - B)At - H_c W_c \qquad (1)$$

where H_c is latent heat of condensation and W_c lb. of water are condensed on the canopy. Assuming $(I - B)$ is constant and differentiating (1):

$$W\mathrm{d}H_w + H_w\mathrm{d}W + G\mathrm{d}H_a = (I - B)At - H_c\mathrm{d}W_c \qquad (2)$$

Further operation on (2) is based on the definitions in Table 3.

Table 3

Enthalpy of water at T_w	$H_w = C_w T_w$
	$\mathrm{d}H_w = C_w \mathrm{d}T_w$
Humidity	$m_a = W_a/G$
	$\mathrm{d}W = \mathrm{d}w_a = G\mathrm{d}m_a$
Enthalpy of air–vapour mixture at T_a	$H_a = C_a T_a + m_a\,[H_{32}^{\circ} + C_w(T_a - 32°)]$
	$= C_a T_a + m_a H_v$
Humid heat	$H_s = C_a + C_w m_a$
Heat transfer	$GH_s\mathrm{d}T_a = h[T_w - T_a]\,A\mathrm{d}t$
Mass transfer	$GH_v\mathrm{d}m_a = k_a\,(P_w - P_a)\,H_v A\mathrm{d}t$
Bowen's ratio for open system (ref. 2)	$R = \frac{K}{LE} = 0{\cdot}46\left(\frac{T_w - T_a}{P_w - P_a}\right)\frac{P}{760}$

K, convection loss to air; L, latent heat evaporation; E, weight of water evaporated.

Applying the definitions in Table 3, it can be shown from equation (2) that:

$$W\Delta H_w + GH_v\mathrm{d}m_a\left[1 + \frac{h}{k_a H_v}\left(\frac{T_w - T_a}{P_w - P_a}\right)\right] = (I - B)At - H_c\Delta W_c \qquad (3)$$

Equation (3), when $\Delta W_c = 0$, may be compared with that for an open system given by Cummings in the nomenclature[3].

$$S + EL\left[1 + 0{\cdot}46\left(\frac{T_w - T_a}{P_w - P_a}\right)\frac{P}{760}\right] = (I - B) \qquad (4)$$

where S is the enthalpy of the water.

Using the heat/mass transfer ratio in Table 3, equation 3 can be simplified to:

$$W\Delta H_w = \left(\frac{M_a}{M_w} k_a P\right)\Delta H_a + (I - B)At - H_c\Delta W_c \qquad (5)$$

where ΔH_w, ΔH_a are the enthalpy changes in time t. From equation 5, if k_a is known, the weight of water evaporated can be estimated. The foregoing and similar enthalpy equations give evaporation-rates of the order obtained experimentally; it is, however, evident from Fig. 2 that equations based on a constant value of $(I - B)$ are only approximations.

The equation for linear conduction in an x-direction is:

$$\mathrm{d}T/\mathrm{d}t = \alpha\,\mathrm{d}^2T/\mathrm{d}x^2 \qquad (6)$$

If the temperature at a surface, $x = 0$, varies in a simple periodic manner:

$$T = T_0 \sin \omega t = T_0 \sin 2\pi t/P \qquad (7)$$

the solution of equation 6 for boundary condition 7 has the established form:

$$T = T_0 \exp(-\mu x)\sin(\omega t - \mu x) \qquad (8)$$

where $\mu = \sqrt{(\omega/2\alpha)}$.

From equation (8), at a depth x, there will be a lag in the temperature wave of phase angle μx; this will amount to a complete period, and phase equality will be attained when $\mu x = 2\pi$ or

$$x = 2\sqrt{(\pi\alpha P)}$$

The solution may be put in the form:

$$\theta = T/T_0 = f(t/P,\ x/2\sqrt{(\pi\alpha P)}) \qquad (9)$$

which can be applied graphically.

Equations 8 and 9 apply to heat conduction through the Earth or solid material where the heat

source is at the surface. In solar evaporation processes there is an absorption of radiation given by:

$$dI_\lambda/dx = -B_\lambda I_\lambda \quad (10)$$

If the radiation energy is plotted against wavelengths for different depths, the total energy reaching a given depth can be estimated graphically. Evidently the results will depend on the physical and chemical properties of the absorbing medium.

Assuming that:

$$I_\lambda = f(\Delta T, k, \rho, c, L, \lambda, t, \mu) \quad (11)$$

the results obtained by dimensional analysis are given in Table 4.

Table 4

$$I_\lambda L/\Delta T k = f(\mu c/k, \rho L\lambda/\mu t) \quad (12)$$

Nusselt number	$N\mu\lambda = IL/\Delta Tk = (I\lambda k)/(\Delta T/L)$
Prandtl number	$Pp = \mu c/k = \nu/\alpha$
Modified Reynolds number	$(Re)\lambda = \rho\lambda L/\mu t = (\rho vL/\mu)\,(\lambda/vt)$

Geometrically similar systems
$N\mu\lambda = f[Pr, Re(\lambda/vt)]$

If, under some conditions, the group:

$$\nu/\alpha \ll (\rho vl/\mu)\,(\lambda/vt)$$

then absorption, at a given wave-length λ at a depth x, is given by:

$$I_{\lambda_0}\{1 - \exp(-B_\lambda x)\}$$

and may depend more on the ratio ρ/μ than on the thermal diffusivity α. Once the radiation is absorbed, and heat generated, conduction will proceed and thermal diffusivity predominate.

These considerations are of interest not only in enthalpy increases and evaporation but also in aqueous quantum processes which occur above a threshold frequency.

The voltage equivalent of the photons is given by:

$$V = hc/e\lambda \simeq 12400/\lambda_{\text{Å}}. \quad (13)$$

Under normal conditions only a small fraction of the total photons may be effective. Also, back reactions reduce the conversion efficiency. If the reaction products could be removed and combined in some ingenious manner, electricity might be generated.

Water, for example, can be decomposed by radiation in the extreme ultra-violet and the electromotive force of the hydrogen–oxygen cell is given by:

$$E = \frac{RT}{zF}\left[\ln K - \ln \frac{C^2_{H_2O}}{C^2_{H_2}C_{O_2}} - \Sigma n_i\right] \quad (14)$$

When evaporation in a solar still is prevented by a surface layer of inert oil, temperatures approaching 80° C. can be obtained; this may increase the quantum efficiency. In general, for reversible, isothermal processes at constant pressure:

$$zFE = \Delta A_T + \Sigma P_a dV_a = -\Delta G \quad (15)$$

When $\Delta A_T = 0$ and if $P_1V_1 = P_2V_2$:

$$E = \frac{RT}{zF}\ln\frac{P_2}{P_1} \quad (16)$$

where P may be a gas pressure or an osmotic pressure in an electrode amalgam.

Further:

$$F[E - T(\partial E/\partial T)] = \Delta H \quad (17)$$

When ΔH (reaction) = 0

$$E = \text{constant} \times T \quad (18)$$

If changes in concentration or pressure can be effected by absorption of solar radiation, the system may function as an engine converting heat into electricity.

In the foregoing and other connexions, solar stills, which can be instrumented for research, offer several interesting possibilities.

Thanks are due to Imperial Chemical Industries, Ltd. (Plastics Division), for the provision of 'Perspex' hemispheres.

[1] Lof, George O. G., U.S. Department Interior, Saline Water Conversion Program, Report No. 5.
[2] Bowen, I. D., *Phys. Rev.*, **27B**, 779 (1926).
[3] Cummings, N., and Richardson, B., *Phys. Rev.*, **30**, 527 (1927). Cummings, N., *Trans. Amer. Geophys. Union*, **21**, 512 (1940); **27**, 81 (1946); **29**, 408 (1948).

MOMENTUM SPECTRUM OF COSMIC RAYS AT SEA-LEVEL

By F. ASHTON, G. BROOKE, M. GARDENER, P. J. HAYMAN, D. G. JONES, S. KISDNASAMY, J. L. LLOYD, F. E. TAYLOR, R. H. WEST and A. W. WOLFENDALE

Department of Physics, The Durham Colleges in the University of Durham

PRELIMINARY results are given of the differential momentum spectrum of μ-mesons in the cosmic radiation at Durham (200 ft. above sea-level). The spectrum is used to make an estimate of the production spectrum of the parent π-mesons.

The measurements have been made with the Durham Cosmic-Ray Spectrograph, which consists of a large electromagnet ($\int Hdl = 6{\cdot}2 \times 10^5$ gauss-cm.), with layers of Geiger counters and neon flash-tubes as the detecting elements. The overall height of the instrument is 4·95 m. and the aperture is ~ 20 sterad. cm.^{2}. The design of the instrument is based on the performance of a small prototype spectrograph, described by Ashton *et al.*[1]. The particle trajectories are traced through four measuring-levels, two placed above and two below the magnet. At each level there is a layer of Geiger counters, each counter being attached to an electronic unit giving pulses characteristic of its position in the layer, and eight close layers of neon flash-tubes. The flash-tubes give a precise indication of the position of a particle accepted by the counter selection system.

The measurements at low momenta have been made with the Geiger counter arrangement alone; an electronic momentum analyser computing the deflexion of each particle from the pulses arriving from the counter units at each level. Some 160,000 particles with momenta greater than 1 GeV./c. have been recorded so far. Corrections have been made for the small flux of protons using the proton spectrum measured by Mylroi and Wilson[2], and the resulting μ-meson spectrum is shown in Fig. 1. Only comparative rates are determined and the flux is normalized to that given by Rossi[3] at

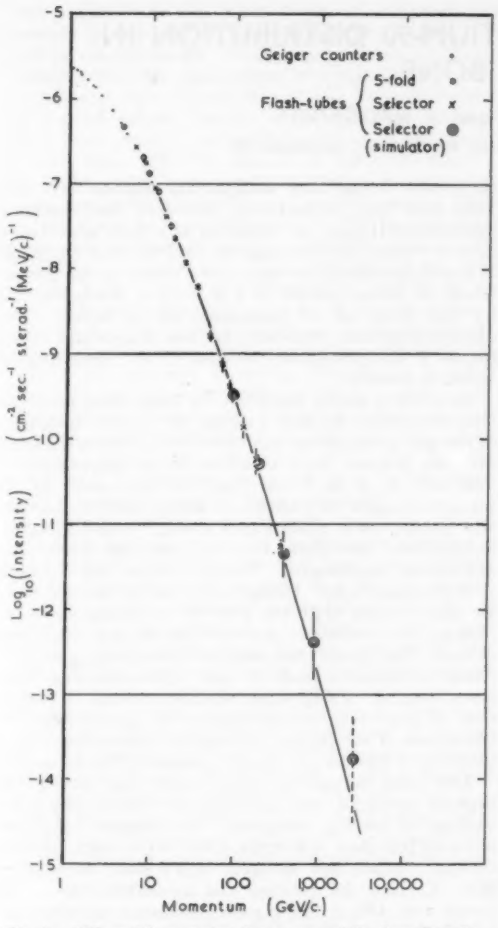


Fig. 1. Differential spectrum of μ-mesons at Durham (200 ft. above sea-level), based on measurements of about 164,000 particles, of which 80 had momenta greater than 100 GeV./c.

1 GeV./c., that is, $2{\cdot}45 \times 10^{-6}$ cm.$^{-2}$ sec.$^{-1}$ sterad.$^{-1}$ (MeV./c.)$^{-1}$.

The measurements have been extended to higher momenta using the arrays of flash-tubes. In order to check the reliability of this technique, a series of photographs has been taken in which the flash-tubes are operated for every particle accepted by the counter system. The measurements are shown in Fig. 1, where they are designated '5-fold' data. The experimental points below 4 GeV./c. have been omitted for clarity. The results are clearly consistent with the counter data.

For good statistical accuracy at higher momenta some selection of particles is required; this is performed by operating the momentum analyser in conjunction with a momentum selector which produces an output pulse only for particles undergoing small deflexions in the spectrograph. Measurements on the flash-tube photographs, made with moderate accuracy using a re-projection system, are sufficient for momenta up tose veral hundred GeV./c. (designated 'Selector' data in Fig. 1). At still higher momenta a more accurate method is required, and a track simulator is used. With this device a detailed study is made of each track at each level, using the information on track location given by both flashed and unflashed tubes. The maximum detectable momentum of the instrument is (1,000 $\pm$ 200) GeV./c. for measurements made in this way; this being the momentum corresponding to a deflexion equal to the probable error of the deflexion measurements. Such results are designated 'Selector (simulator)' in Fig. 1.

Comparison has been made with various other spectra. Below 20 GeV./c. the spectrum is consistent with the results of Owen and Wilson[4] and Caro *et al.*[5]. Between 20 GeV./c. and 200 GeV./c. there is agreement with the spectra of Pine *et al.*[6] and Holmes, Owen, Rodgers and Wilson[7], but not with that of Caro *et al.*[5].

The form of the production spectrum of the π-mesons, whose decay gives rise to the μ-mesons, is an important derivation from the sea-level μ-meson spectrum. Puppi[8] has derived the exponent of the π-meson production spectrum, γ, using the earlier sea-level spectra, with the result that γ is about 2·47 over the range 1–10 GeV./c. and increases slightly at higher energies. Our result is consistent with this conclusion.

Above 20 GeV./c. the exponent has been derived from the analysis of Barrett *et al.*[9]. Using simplifying assumptions, these workers show that a π-meson production spectrum of exponent γ gives rise to a sea-level differential μ-meson spectrum of the form $N(p) \propto \frac{1}{p^{\gamma}}\left(\frac{1}{1 + p/90}\right)$ (with p in GeV./c.). We have corrected this relation for the momentum loss of μ-mesons in the atmosphere and loss by μ–e decay, and compared it with the experimental results for various values of γ. The exponent giving the best fit is $\gamma = 2{\cdot}55$, and the spectrum using this exponent is shown as the full line in Fig. 1. The conclusion to be drawn from the study of the π-meson production spectrum is that there is little change in the exponent over the range 1–500 GeV./c. This conclusion is of interest in connexion with the high exponent ($\gamma \sim 4{\cdot}3$) inferred from the work on γ-ray cascades reported by Duthie *et al.*[10].

The slope of the sea-level μ-meson spectrum increases continuously with momentum, reaching a value of $-3{\cdot}2$ over the range 100–1,000 GeV./c.

A fuller account of the present work will be published elsewhere.

We thank Prof. G. D. Rochester for his encouragement and interest in all stages of the work.

Grateful acknowledgement is made to the Department of Scientific and Industrial Research for the award of several Special Research Grants and Studentships. Thanks are also due to Profs. P. M. S. Blackett, S. Devons and J. G. Wilson, for their co-operation in making available the large electromagnet.

[1] Ashton, F., Nash, W. F., and Wolfendale, A. W., *Proc. Roy. Soc.*, A, **253**, 163 (1959).
[2] Mylroi, M. G., and Wilson, J. G., *Proc. Phys. Soc.*, A, **64**, 404 (1951).
[3] Rossi, B., *Rev. Mod. Phys.*, **20**, 537 (1948).
[4] Owen, B. G., and Wilson, J. G., *Proc. Phys. Soc.*, A, **68**, 409 (1955).
[5] Caro, D. E., Parry, J. K., and Rathgeber, H., *Aust. J. Sci. Res.*, A, **4**, 16 (1951).
[6] Pine, J., Davisson, R. J., and Greisen, K., private communication and Proceedings of the International Cosmic Ray Conference, Moscow, 1959 (in the press).
[7] Rodgers, A. L., Ph.D. thesis, University of Manchester (1956).
[8] Puppi, G., "Progress in Cosmic Ray Physics", 3 (North Holland Pub. Co., Amsterdam, 1956).
[9] Barrett, P. H., Bollinger, L. M., Cocconi, G., Eisenberg, Y., and Greisen, K., *Rev. Mod. Phys.*, **24**, 133 (1952).
[10] Duthie, J., Fisher, C., Fowler, P. H., Kaddoura, A., Perkins, D. H., and Pinkau, K., 1960, Proceedings of the International Cosmic Ray Conference, Moscow, 1959 (in the press).

DETERMINATION OF STRONTIUM-90 DISTRIBUTION IN HUMAN BONE

By R. BJÖRNERSTEDT and S. HÄGGROTH

Research Institute of National Defence, 4th Division, Stockholm 80

THE level of strontium-90 in human bone as a result of fall-out has been determined by Kulp *et al.*[1] to be 0·19 μμc./gm. calcium (S.U.) as of January 1958. This value is a world average for adult skeletons. If data for children are included, the average value becomes 0·52 S.U., but there is a variation of the strontium concentration with age, giving a maximum at about 1 year of 1·5 S.U. These levels change with time, however, and Kulp estimates that a maximum concentration in young children will occur at about 1966, on the average corresponding to 4 S.U. and none exceeding 80 S.U. (assuming no further testing).

For an evaluation of the possible biological effects of the strontium burdens cited, it may be of importance to know the distribution of strontium-90 inside the skeleton[2]. From what is known about the metabolism of strontium in bone it is to be expected that the unevenness of the distribution should vary with age and date of birth[3]. For children born after 1954 one would, for example, expect a fairly diffuse and uniform labelling of the bone, while, on the other hand, for individuals born in 1934 or earlier some diffuse and some 'hot-spot' labelling should occur. From, for example, the work of Schulert *et al.*[4] it is evident that an uneven distribution does, in fact, occur if the strontium-90 activity of different bones or different parts of the same bone are compared. The existence at present of hot spots in human bone has, however, not been proved or disproved directly. This would most readily be done with an autoradiographic technique, but the present strontium-90 levels in human bone have been considered too low for this technique to be useful. This assumption will be discussed here. If strontium-90 in bone (varying between 0·1–100 S.U. for different individuals and at different times) is to be studied autoradiographically it is necessary to consider what other activities may be found in bone. For comparison, 1 S.U. corresponds to 0·31 betas/min./gm. of bone from strontium-90 (0·55 MeV.) and the same number from yttrium-90 (2·26 MeV.).

Of the naturally occurring radioisotopes, potassium-40 dominates. 880 p.p.m. potassium in bone[5] gives 1·53 betas/min./gm. bone. Carbon-14 gives 3·2 betas/min./gm. bone[3], but with a maximum energy of only 155 keV. against 1·3 MeV. for potassium-40. Radium-226 is present in small amounts, a body burden of 10^{-10} gm. giving about 0·07 alpha and 0·05 beta/min./gm. bone. Bone may contain other activities besides strontium-90 from fall-out. At present, when no new nuclear weapons tests have been carried out for more than a year, only cæsium-137 could compete. A value of around 0·13 beta/min./gm. bone is to be expected.

If a thick bone sample is autoradiographed, the activities mentioned will have the following importance in approximate relation to 1 S.U. strontium-90: strontium-90, 1·0 by definition; potassium-40, 2·3; radium-226, 1·2; carbon-14, 0·5; and cæsium-137, 0·08. This is comparing the dosages at the surface of a thick bone sample. The maximum ranges of carbon-14 betas and radium-226 alphas are only 100μ and 35μ, respectively, however, and so these contributions may be excluded if a thin absorber is used between the bone sample and the film emulsion. It is still apparent, though, that a study of the present levels of strontium-90 (0·1–2 S.U.) is made difficult by the presence of potassium-40 in bone. This difficulty should, however, be less important in the future if the predicted increase of the strontium-90 levels is found.

In order to avoid disturbances from other activities than strontium-90 and yttrium-90, a new technique of sample preparation has been tried. When a sample of fresh human bone is ashed at a temperature of 700–800° C. it is found that the geometry of the sample changes very little. A section of, for example, the femur, some millimetres thick, becomes slightly twisted and shrunken, but the essential dimensions are almost unchanged. This is true as well for areas of trabecular bone. Using highly active animal bone, we have found that the process of ashing does not change the strontium distribution to any noticeable extent. Hot spots that existed before ashing are still found afterwards and no new concentrations have been created. From what is known about the structure of bone one would expect the geometrical distributions of strontium in fresh and ashed bone to be identical if the bone keeps its geometry during ashing.

The bone sample is white after the ashing, all organic material and particularly carbon (and thus carbon-14) having vanished. The content of potassium-40 has been determined by γ-spectrometry on a 500-gm. femur ash sample. (We are indebted to Mrs. K. Löw for making the measurements.) The result was 430 ± 120 p.p.m. potassium in bone ash, which corresponds to 180 ± 50 p.p.m. in fresh bone. This value is only 20 per cent of that in ref. 5. The difference may perhaps be explained by variations in the preparation of the bone before ashing. In our case, as much as possible of the organic material was removed beforehand. The sample measured was too small to demonstrate the presence of any cæsium-137.

The low value found for potassium-40 in bone ash reduces the effect on the determination of strontium-90 discussed previously from 2·3 to less than 0·5 (strontium-90 = 1·0). A still further reduction may be achieved if the ashed bone sample is carefully soaked and washed with water or ammonium carbonate solution. In this way, 570 p.p.m. of potassium-40, that is, between 90 and 100 per cent, has been extracted from the above-mentioned femur sample. The same is most probably true for cæsium-137 as well, although it has not been possible to check this as yet. A similar extraction carried out on highly active (strontium-90) animal bone revealed that only a small fraction (1–2 per cent) of the strontium is removed in the process. This should apply to radium-226 as well. It is thus possible to prepare bone samples which contain almost only strontium-90 + yttrium-90 and radium-226 activity (for 1 S.U.: strontium-90 = 1·0; radium-226 ~ 1·2; potassium-40 < 0·05; cæsium-137 < 0·01; and carbon-14 ~ 0).

One might now ask what times of exposure are necessary to produce an autoradiograph of these low levels of strontium-90. 1 S.U. corresponds to about 1 beta/cm.²/hr. on the surface of a sample of bone[6]. Using X-ray film ('Kodirex') it has been reported[7] that a good autoradiogram is produced in 80 days with a bone sample containing not more and probably less than 126 S.U. In about the same time 'a very slight image' was produced with a sample containing not more than 11 S.U. Similar results have been obtained in our laboratory. These exposures should correspond to about 250,000 and 25,000 betas/cm.², respectively. It is interesting to note that the hard cosmic-ray component would in an 80-day exposure contribute about 120,000 tracks/cm.² of emulsion. To make possible autoradiographs on the 1 S.U. level this high background must be reduced. A factor of 10 may, however, be gained through storage in a shelter with a 20-m. rock roof. Additional lead shielding of the films is then required to absorb the γ-radiation from both the rock itself and from radon with daughter products. In this way, a film background over 80 days of less than 10,000 tracks/cm.² should be a possibility.

In addition to this it would be necessary to reduce the thermal and chemical blackening that takes place during storage and which over a year may increase from, for example, 0·06 to 0·30 (ref. 8). A twofold reduction of this blackening results if the film is stored at low temperature (between − 5° C. and + 5° C.). The blackening due to carbon-14 and tritium in the emulsion, finally, is negligible in comparison with the cosmic ray background.

Granted that underground cold-storage is effective in reducing the background blackening of X-ray films, it is reasonable that 100,000 betas/cm.² should produce a good autoradiogram and 10,000 betas/cm.² a very slight one on 'Kodirex' film. For 1 S.U. this corresponds to exposure times from about 10 and 1 years, respectively. Comparing 'Kodirex' with other X-ray films, the following figures for relative speed may be cited[9]: 'Kodirex', 35; '*CEA* Textur-*X*', 47; 'Ilfex', 52; Ilford Industrial *G*, 57; Kodak Industrial *K*, 77; and Fuji Industrial 200, 100. Up to a factor of 2–3 in exposure time may thus be saved using films that have high speed. Additional time may possibly be saved if local strontium-90 concentrations occur.

A second way to use autoradiography to study the labelling of human bone with strontium-90 is with β-sensitive nuclear emulsions. To begin with, the emulsion would have to be cleaned from the existing background of β-tracks. This is possible with a water-vapour treatment for some hours at 50–60° C.[10]. Subsequent exposure to attain 10^3–10^4 betas/cm.² may produce results that are measurable by microscopic scanning[11].

It may thus be possible, using an exposure time of one year, to get a weak autoradiogram of bone carrying 1 S.U. diffusely distributed. This type of distribution corresponds to that of bones from children younger than fifteen years (0·7–1·5 S.U.). For adults having an average of 0·19 S.U. (January 1958) it is to be expected that local concentrations will occur, some parts of the bone containing strontium-90 in excess of 1 S.U. This should again be observable with exposure times of about a year. An increase of the future strontium-levels would make the autoradiographic method still more feasible.

[1] Kulp, J. L., Schulert, A. R., and Hodges, E. J., *Science*, **129**, 1249 (1959).
[2] Björnerstedt, R., and Engström, A., *Science*, **129**, 327 (1959).
[3] Report of the United Nations Scientific Committee on the Effects of Atomic Radiation, Supp. 17 (*A*/3838) (1958).
[4] Schulert, A. R., Hodges, E. J., Lenkoff, E. S., and Kulp, J. L., *Health Phys.*, **2**, 62 (1959).
[5] Report of the Internal Dose Committees of the I.C.R.P. and N.C.R.P.-1958 Revision, B. Lindell (private communication).
[6] Rossi, H. H., and Ellis, jun., R. H., *Nucleonics*, **7**, No. 1, 18; No. 2, 19 (1950).
[7] Hawthorn, J., and Duckworth, R. B., *Nature*, **182**, 1294 (1958).
[8] Sjöstedt, G., CEA-verken, Strängnäs (private communication).
[9] Smits, D. W., *et al.*, *Acta Cryst.*, **9**, 520 (1956).
[10] Marguin, G., Wissenschaftliche Photographie, Internationale Konferenz, Köln (1956).
[11] Kristiansson, Dr. K., Lund (private communication).

POTATO WART DISEASE, *SYNCHYTRIUM ENDOBIOTICUM* (SCHILB.) PERC.

By VÍT BOJŇANSKÝ

Plant Protection Laboratory, Ivanka pri Dunaji, Czechoslovakia

IT was thought in the past that the potato wart fungus could exist equally well in cold as in warm or even sub-tropical regions, that is, in all places where potatoes[1,2] are cultivated. This opinion diverted attention from the investigation of ecological factors affecting the fungus in its environment. Uncertainty about this led me to a detailed study of the genesis and disappearance of the first occurrence of potato wart disease in Europe[3,4], to the laying down of field tests in sub-arid and arid regions, and to the utilization of data about the historical and present occurrence of potato wart disease throughout Europe.

Analysis of the climatic conditions of the district of Hornany in Czechoslovakia, where potato wart disease was first described[4], shows that the disease ceased to exist after a drier and warmer period[3].

Field tests in the sub-arid region of Czechoslovakia showed that among tubers harvested in humid regions from land in an area where there had been a marked appearance of potato wart disease no case of the disease was found. However, when every potato plant was given 5 kgm. of totally infected soil from the humid area where the Wohltmann variety crop was 90–95 per cent destroyed, a small amount of wart disease was registered in the first year, a smaller amount in the second year, and little or nothing in the third year (Fig. 1). Very often the out-growths were atypical. When in the period 1951–58 the gradually infected soil was brought back from the sub-arid region to a humid area (5 kgm. of totally infected soil for each potato plant) the appearance of wart disease was detected as shown in Fig. 2. It was also found that when totally infected soil from the humid area was placed in the sub-arid region without being mixed with the soil of that region the amount of wart disease was greater, and the cleansing of the soil from the fungus slower. In the fourth year the disease was sporadic or lacking. In the humid area in the same soil wart disease was proportionately greater (Fig. 3).

Judged from the results obtained, the practical eradication of the potato wart fungus from the soil in sub-arid regions does not take long even when the soil is strongly infected (2–3 years), though complete eradication takes longer (5–7 years) and this happens even when non-immune varieties of potatoes are grown.

Analysis of the occurrence of wart disease in European States from the climatological–geographical point of view demonstrated that the greatest intensity is in the mountainous and sub-mountainous regions of central, northern and eastern Europe. In the maritime countries by the North Sea (Great Britain, Benelux, Northern France) there is a smaller and economically less significant amount, however humid and mild the

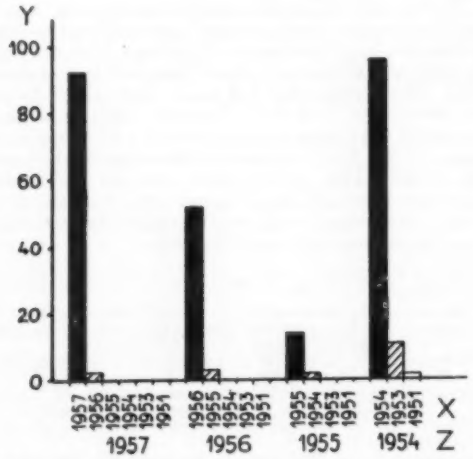


Fig. 1. Intensity of wart disease in sub-arid regions on soil highly infected (5 kgm. totally infected soil from the humid area to each potato plant). X = year of infestation of the soil; Y = weight of outgrowths in gm.; Z = year of the experiment

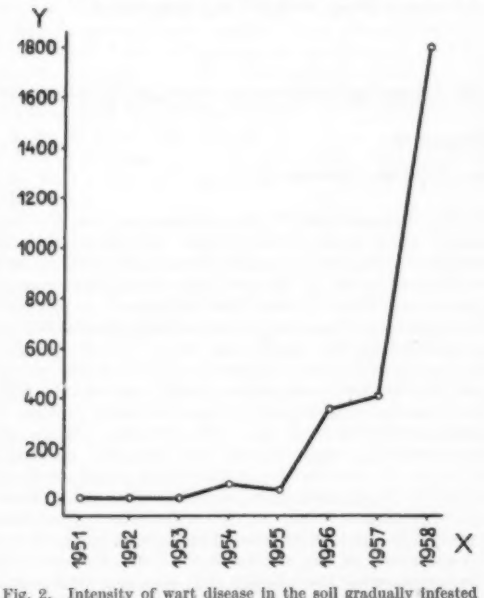


Fig. 2. Intensity of wart disease in the soil gradually infested (5 kgm. totally infested soil to one potato plant) in the sub-arid region in 1951–58 and in 1958 brought into humid region. X = year of infestation of the soil; Y = weight of outgrowths in gm.

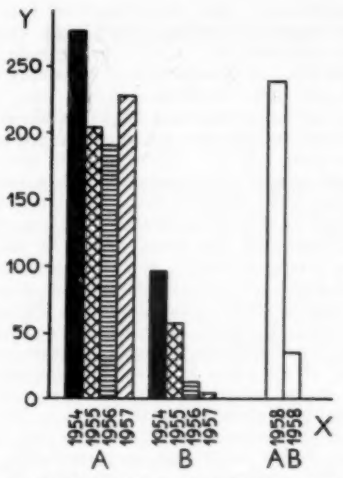


Fig. 3. Intensity of wart disease in totally infected soil, placed in 1954 in the humid *A* and sub-arid *B* regions and in 1958 returned to the humid region. X = year of experiment; Y = weight of outgrowths in gm.

climate. In the warmer regions of southern Europe, and the sub-arid plains of central Europe having a continental climate, wart disease has not been reported.

Temperature and rainfall, and to a certain extent the nature of the soil, are the most decisive factors in the successful or unsuccessful development of the fungus.

The potato wart fungus likes climates which may be characterized thus: low summer temperature (under 18° C.), long and deep winters (160 and more days with temperatures below 5° C.), heavy precipitation (700–800 mm. and more per annum, the greater part during the summer), sufficiently aerated and extensively cultivated soil, with an acid reaction and poor rotation of crops, where potatoes are planted every second or third year. In areas with mild, short winters many zoosporangia germinate without infection taking place. Rapid cleaning of the soil follows, and the appearance of wart disease is sporadic or nil and economically of no importance.

The results of the investigations have made it possible, first, to establish for Europe a prognosis of the occurrence of potato wart disease, according to which suitable, less suitable, and unsuitable zones can be fixed for the contamination and development of potato wart disease; secondly, to regulate the breeding and cultivation of potatoes. In the unsuitable zone it is possible without apprehension to cultivate non-immune varieties of potatoes, many of which are more tolerant to degeneration and important from the point of view of production of early potatoes. Finally, it is possible to solve plant quarantine questions, and control the disease according to the individual ecological–geographical zones.

Further details will be given in my book, "Ecology and Prognosis of Potato Wart Disease", to be published with an extensive English summary by the Slovak Academy of Sciences Press in 1960.

[1] Bordukova, M. B., Bolezni i vrediteli kartoffl'a. Moskva, Gos. izdat. selchoz. lit. (1955).

[2] E.P.P.O., Potato Wart Disease in Europe in 1954: European and Mediterranean Plant Protection Organization, Paris (1955).

[3] Bojnanský, V., *NachrBl. deutsch. PflSchDienst, Berl.*, **11**, 109 (1957).

[4] Schilberszky, K., *Ber. deutsch. bot. Ges.*, **14**, 36 (1896).

LETTERS TO THE EDITORS

PHYSICS

Self-quenching Geiger Counters containing Mixtures of Permanent Gases

We have investigated the characteristics of Geiger–Müller counters containing mixtures of argon with small quantities of xenon (0–7 per cent), oxygen (0–0·5 per cent) and nitrogen (~ 1 per cent), to total pressures of 700 mm. mercury. That counters filled with this mixture would behave as 'fast' counters in a manner similar to organically quenched counters was first reported by Shore[1], although Riedel[2] reported that using the filling recommended by Shore produced no Geiger region. Using counters of the conventional 'gamma' type, glass bodies with cylindrical cathodes of various materials together with a 4·7 megohm series resistor and a linear amplifier of a gain of about 25, we find that optimum proportions of the gas mixture to produce the best plateaux are: xenon (3·5 per cent), oxygen (0·3 per cent), nitrogen (1·2 per cent), with argon added to give a total pressure of 700 mm. mercury. Such a mixture gave a plateau about 170 V. in length, with a starting voltage of 1,460 V. and a plateau slope of 0·02 per cent/V.

Some fairly general conclusions can be reached as to the role of the various components in the mixture in producing the Geiger plateau. It is evident that the oxygen makes possible the rapid spread of the discharge along the counter anode, chiefly by photo-ionization, in the manner described by Huber[3]. This was made clear when fillings of pure argon and argon plus 1 per cent xenon were investigated, by examination of the discharge by oscilloscope. It was found that with both these mixtures there was no Geiger region, the discharge passing abruptly from the proportional to the corona region, the voltage at which this occurred being lowered from 1,850 V. to 1,260 V. with the addition of xenon. Addition of 0·1 per cent of oxygen to pure argon altered the character of the discharge entirely, the familiar Geiger pulses being observed although a plateau of only a few volts was obtained with many spurious pulses.

Although Shore reported that, if nitrogen were not present in the mixture, the plateau became extremely short, we have not found this to be so. The addition of about 1 per cent of nitrogen improves the performance of the counters but is not essential. For example, a counter containing the optimum quantities of xenon and oxygen had a plateau of 102 V. in length with a slope of 0·064 per cent/V. Refilling and adding 1 per cent of nitrogen resulted in an increase in length to 130 V. and the slope improved to 0·025 per cent/V.

It is also clear that the presence of the xenon inhibits the formation of the many spurious pulses found in the argon–oxygen–nitrogen mixtures. Adding small quantities of xenon to the latter results in an improvement in length and slope of the plateau together with a very sharp fall in the starting voltage, from 2,124 V. for zero quantity to 1,460 V. for the optimum amount of xenon (3·5 per cent). Adding further xenon results in an increase in the starting voltage, and a deterioration of the slopes and lengths of plateaux.

In an endeavour to understand this mechanism we have investigated the time incidence of spurious pulses by pulse-interval analysis[4] for mixtures containing increasing quantities of xenon with fixed amounts of nitrogen (1 per cent) and oxygen (0·3 per cent). At the same time we have measured the transit times of the front of the positive-ion sheath from examination of the cathode-current pulse. In all the many fillings investigated we have found that the maximum number of spurious pulses occur at the end of the counter dead-time and only a negligible proportion are recorded after the front of the positive-ion sheath has reached the cathode. It is apparent, at any rate with these counters, that the positive-ion effect at the cathode, often quoted as the reason for the generation of spurious pulses in Geiger counters, is unimportant.

The other possible mechanism is that the spurious pulses are due to hard photons, delayed relative to the main Geiger pulse, releasing photo-electrons at the cathode. Such hard photons could arise as a result of the quenching of argon metastables by collision with gas molecules. In fact, pulse-interval analysis of mixtures containing zero or less than optimum quantities of xenon shows large numbers of small spurious pulses occurring in as short a time as 15 μsec. after the main Geiger discharge. With optimum quantities of xenon such small pulses do not appear and the counters have a clear dead-time of about 150 μsec., indicating that the argon metastable states are rapidly quenched by collisions with xenon atoms. That this occurs, and with the formation of ions, is also indicated from the considerable lowering of starting voltage with addition of xenon, while the charge per pulse remains of the same order. The ionization potential of xenon (12·127 V.) is higher than both metastable levels of argon (11·53, 11·72 V.) so that direct ionization of xenon atoms by collision with argon metastable states is not possible; but in spite of this it seems fairly evident that some mechanism exists involving interaction between xenon atoms and argon metastable states giving rise to an increase in the number of ions produced in the avalanches.

A more detailed report of the work described in this communication is to be published elsewhere.

A. J. L. Collinson
I. C. Demetsopoullos
J. A. Dennis
J. M. Zarzycki

The Borough Polytechnic,
London, S.E.1.

[1] Shore, L. G., *Rev. Sci. Instr.*, **20**, 956 (1949).
[2] Riedel, O., *Z. Naturforsch.*, **5a**, 331 (1950).
[3] Huber, E. L., *Phys. Rev.*, **97**, 261 (1955).
[4] Putman, J. L., *Proc. Phys. Soc.*, **61** 312 (1948).

An Image Intensifier with Transmitted Secondary Electron Multiplication

The use of transmitted secondary electron emission for electron multiplication has been proposed by Lubszynski[1], McGee[2] and Sternglass[3], and photoemissive image intensifiers incorporating thin films of potassium chloride as transmitted secondary emitters have been described by Wachtel, Doughty and Anderson[4]. We also have been experimenting with the construction of image intensifiers of this kind.

The form of the tubes we have made is shown in Fig. 1. They consist essentially of an antimony–cæsium photocathode, an aluminium-backed zinc sulphide–silver phosphor, and between these a set of parallel electron-multiplying dynodes which are layers of aluminium and potassium chloride deposited on a supporting film of aluminium oxide. Electrons from the photocathode are accelerated and focused on the first dynode by means of coaxial electric and magnetic fields, and secondary electrons are produced which escape from the dynode on the side remote from the photocathode. These transmitted secondaries are similarly accelerated and focused on the second dynode, where further transmitted secondary electrons are produced; and this process is repeated down the tube. Finally, the electrons which emerge from the last dynode are accelerated and focused on the phosphor.

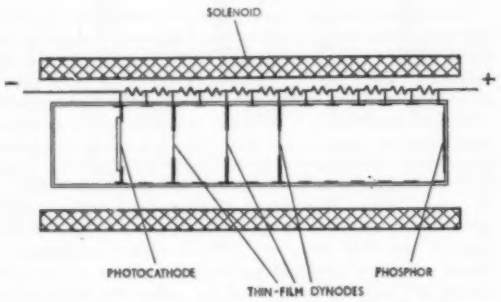


Fig. 1. Image intensifier with transmitted secondary electron multiplication

The electric field is provided by cylindrical electrodes on the inner wall of the tube, which are connected to an external potential divider. The magnetic field is provided by a long solenoid which surrounds the tube. In order to prepare the photocathode without admitting cæsium to the working section of the tube we have made use of the arrangement described by McGee[5]. At a short distance from the front window of the tube there is an annular metal shelf which fits the inside of the tube closely enough to act as a barrier to cæsium vapour, and a glass plate is held to this shelf by means of a spring catch which can be released by tapping the outside of the tube. The photocathode is formed on the surface of the plate which faces the front window of the tube. After the tube is sealed off from the pumps, the plate is released and turned over so that the photocathode faces the dynode system.

The tube we have prepared most recently has five 1-cm. diameter dynodes, each consisting of a layer of aluminium ~200 A. thick and a layer of potassium chloride ~500 A. thick deposited on a film of aluminium oxide ~450 A. thick. The sensitivity of the photocathode is 20 μamp./lumen. We have operated

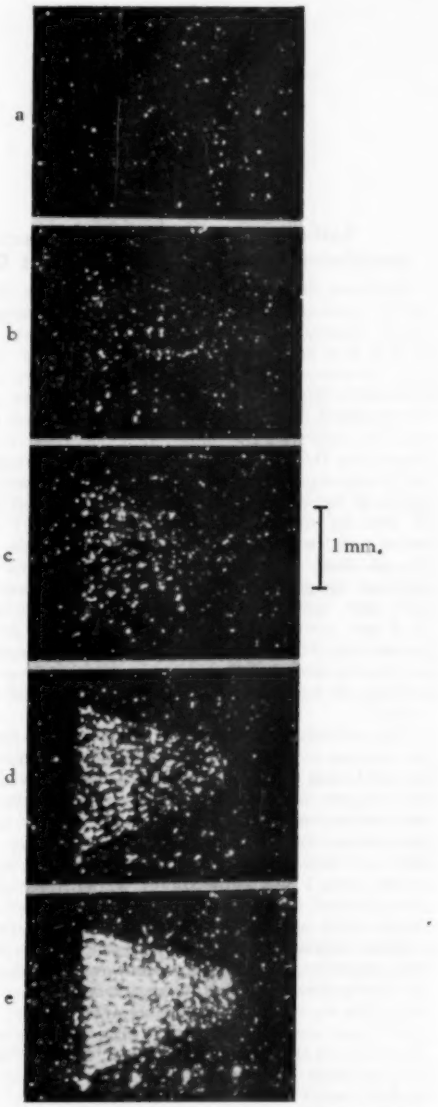


Fig. 2. Photographs obtained with image intensifier showing scintillations resulting from single electrons leaving the photocathode: *a*, dark background; *b*, *c*, *d*, *e*, image of fan-shaped test object projected on photocathode with successively increased levels of illumination. Exposure times 0·5 sec.

this tube with 37 kV. between photocathode and phosphor. The potential difference between the cathode and the first dynode, and between successive dynodes, is then about 4·9 kV., and the magnetic field required for focus is 180 gauss. Under these conditions the total electron multiplication is $\sim 3{\cdot}5 \times 10^3$, and the ratio of total light output to light input is $\sim 8 \times 10^4$ when the incident light is of the same mean wave-length as the phosphor emission. The sensitivity of the photocathode corresponds to a quantum efficiency of about 4 per cent at this wavelength, so that each electron leaving the cathode must result on average in a pulse of about 2×10^6 photons from the phosphor. These pulses are easily visible

with a low-power microscope as bright scintillations on the phosphor, with diameters of about 40 microns. For an average scintillation the photon density at the phosphor thus exceeds 10^{11} photons cm.$^{-2}$, and since a photon density of 10^{8} photons cm.$^{-2}$ is sufficient to give a detectable image on a very fast photographic emulsion[6], it is to be expected that the scintillations can be photographed with relatively inefficient optical coupling between the phosphor and the emulsion.

We have been able to take such photographs (Fig. 2) on Kodak Tri-*X* film, using a pair of 50 mm. *f*/2 lenses front-to-front to give unity magnification. The exposure time for each photograph was 0·5 sec. Fig. 2*a* was taken with the tube in the dark at room temperature, and shows the scintillations due to dark emission from the photocathode. The rate of background scintillation is $\sim 6 \times 10^{3}$ cm.$^{-2}$ sec.$^{-1}$. The corresponding cathode dark current, if each electron emitted gives rise to a scintillation, is $\sim 10^{-15}$ amp. cm.$^{-2}$, which is a reasonable value for an antimony–cæsium cathode. For Figs. 2*b*, *c*, *d* and *e*, the image of a resolution test object was projected on to the photocathode with successively increased levels of illumination. The test object was a fan of 15 black-and-white line-pairs. In Fig. 2*b* the illumination is so low that the photo-emission is only of the same order as the dark emission, and the object is detectable only as a local increase in the scintillation density. Increases in illumination lead to the object becoming barely recognizable (Fig. 2*c*), and clearly so (Figs. 2*d*, *e*). The limiting resolution is about 15 line-pairs per mm., and is determined largely by the diameters of the scintillations.

We are grateful to Prof. J. D. McGee for his interest and encouragement, and to the Department of Scientific and Industrial Research for financial support.

W. L. Wilcock
D. L. Emberson
B. Weekley

Department of Physics,
Instrument Technology Section,
Imperial College, London, S.W.7.

[1] Lubszynski, H. G. Brit. Pat. No. 457493 (1935).
[2] McGee, J. D., Brit. Pat. No. 504927 (1937).
[3] Sternglass, E. J., *Rev. Sci. Instr.*, **26**, 1202 (1955).
[4] Wachtel, M. M., Doughty, D. D., and Anderson, A. E., Proc. Symposium: Photo-electronic Image Devices ("Advances in Electronics", **12**) (Academic Press, New York and London ; in the press).
[5] McGee, J. D., Proc. Symposium: "The Present and Future of the Telescope of Moderate Size", 35 (Univ. of Pennsylvania Press, 1956).
[6] Value quoted by Perl, M. L., and Jones, L. W., Proc. Symposium : Photo-electronic Image Devices ("Advances in Electronics", **12**) (Academic Press, New York and London ; in the press).

Ultrasonic Velocities in Aqueous Solutions of Cadmium Iodide and Mercuric Chloride

In the course of a systematic study of the ultrasonic behaviour of aqueous solutions of inorganic salts, I have come across two cases (mercuric chloride and cadmium iodide) which behave in a peculiar manner. Preliminary measurements on the velocity of ultrasonic waves in aqueous solutions of the above salts have been made using a variable path interferometer working at 750 kc./sec. An accuracy of 0·15 per cent is obtained. The results are presented graphically in Fig. 1.

In contrast with the normal behaviour of electrolytes, ultrasonic velocities of these solutions decrease with increasing concentration. Cadmium iodide registers a large decrease. Ultrasonic velocity at a concentration of 1·75 *M* is 1,369 m./sec., resulting in a lowering of 140 m./sec. from the value for pure water. Mercuric chloride shows a relatively smaller change, the velocity in its 0·25 *M* solution being 1,489 m./sec.—a lowering of 18 m./sec. Even though the ultrasonic velocities decrease with increasing concentration, the adiabatic compressibility decreases with increase of concentration. Full details of this investigation will be published shortly.

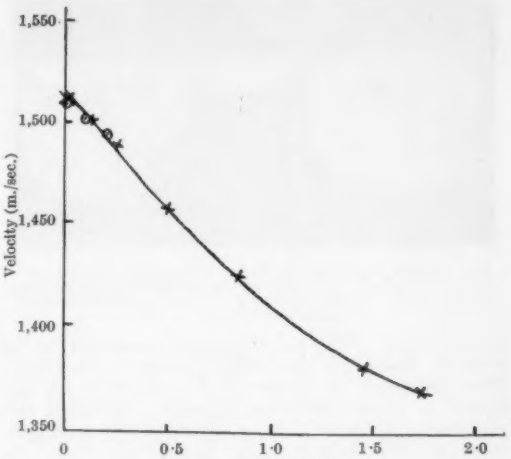


Fig. 1. ×, cadmium iodide ; ○, mercuric chloride

I am indebted to Dr. J. Bhimasenachar for his encouragement and helpful discussions during the course of this work.

S. V. Subrahmanyam

Department of Physics,
Sri Venkateswara University,
Tirupati, India. Nov. 21.

A Sidewall Friction Effect during Soil Consolidation

In the course of investigating the consolidation properties of a sensitive marine clay, a variety of consolidation test procedures has been used. Some followed normal incremental loading procedure, but with widely varying increment ratios. Other tests employed continuous loading techniques either by straining the specimen at a constant rate or by applying load at a constant rate.

When the specimens were oven dried after test, an unusual phenomenon was observed. Specimens that had been subjected to incremental loading revealed a dark ring of soil at mid-height around the perimeter. During the drying this ring of soil appeared to shrink more than the rest of the specimen ; it often fell away leaving a spool-shaped specimen as shown in Fig. 1. The phenomenon was never observed on specimens subjected to continuous loading.

In a paper[1] which describes this work more fully, it is reasoned that the differential shrinkage in specimens loaded in increments is a manifestation of unequal stress distribution across the specimen and that sidewall friction between specimen and enclosing ring is the primary cause of the non-uniformity. Reference to probable effective stresses through incrementally loaded specimens suggests that unequal consolidation will occur, but that in continuous

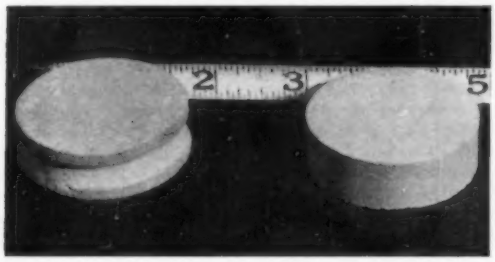


Fig. 1. Differential shrinkage of oven-dried sample due to unequal stress distribution. Specimen on left subjected to incremental loading $\Delta p/p = 1$; specimen on right tested by a continuous load increase technique

loading tests (pore water pressure assumed to be zero) a more uniform consolidation is visualized. This appears to have an important effect on the measured preconsolidation pressure. Although the phenomenon reported was observed in a highly compressible, sensitive clay it may be found in other soils.

Carl B. Crawford

Soil Mechanics Section,
Division of Building Research,
National Research Council,
Ottawa.

[1] Hamilton, J. J., and Crawford, C. B., "Improved Determination of Preconsolidation Pressure of a Sensitive Clay", submitted to the Amer. Soc. Testing Mat.

METALLURGY

Interstitials and Fracture of Metals

Interstitial alloying elements, even in minute quantities, exert a potent influence on the mechanical behaviour of alloys. Of particular recent interest has been the behaviour of hydrogen in steels; where the phenomenon of hydrogen-induced delayed brittle failure has received special attention[1–9]. Time-dependent brittle failure implies that spontaneous brittle fracture will occur at loads substantially below those that may have been previously successfully sustained. The characteristic features are: (*a*) an incubation period; (*b*) slow crack propagation; (*c*) a lower critical stress below which failure will not occur. Both the incubation period for crack initiation and crack growth are controlled and paced by the diffusion of hydrogen[4–6,8].

The incubation period depends on the time required to accumulate a critical concentration of hydrogen in the region of maximum triaxiality. Diffusion to this region is induced by the strain gradient associated with the inhomogeneous stress field, wherein the strain gradient acts as an activity gradient or driving force. It has been demonstrated recently[9] that the attainment of the critical hydrogen concentration is determined by the magnitude of the applied stress. That is, the applied stress governs the magnitude of the strain gradient. High triaxial stress states are brought about by notches. The notches may be artificial (excavated), inherent (inclusions, grain boundary intersections, dislocation arrays, etc.) or combinations of these. However, when brittle fracture is involved, modern theory requires one of the effective notches to be a dislocation array. Therefore, coupled with the strain gradient of an artificial notch may be an additional driving force associated with a dislocation array at the base of the notch. All this suggests that there are two criteria for delayed brittle failure; specifically, a critical concentration of hydrogen and a critical stress state. These two criteria are the basis of the discontinuous nature of crack propagation which is a unique characteristic of this type of time-dependent brittle failure.

The occurrence of discontinuous crack propagation makes it difficult to rationalize delayed brittle failure by applying any mechanism which postulates raising the flow stress to the fracture strength. On the other hand, a decrease in the cohesive strength of the lattice provides a ready explanation for this phenomenon. This could be brought about by localized concentration of interstitial atoms in the region of the critical stress state in the form of an uncondensed atmosphere[10]. Probably a more general situation would be one which involves both a rise in flow stress brought about by plastic deformation and a lowering of the cohesive strength. Presumably the proportions of these two could vary over a wide range.

Once the crack has been initiated, it will be propagated until it exceeds the radius of influence of the accumulated interstitials. Beyond this point the moving crack will be damped out rapidly due to plastic flow ahead of the crack. Another incubation period is then required to build up the critical concentration at the tip of the crack. This step-like process continues until the effective area is reduced such that the applied stress is equal to the notched strength of the material. Thus, a lion's share of the time to failure resides in the sum of the successive incubation periods.

No restrictions are apparent which limit this behaviour to hydrogen and steel. Indeed, the only restrictions to a general behaviour of this type are that a critical stress state exists and that the interstitials have sufficient mobility to attain a critical concentration in a reasonable length of time. Hence, one may well anticipate that any interstitial in any metal which can accommodate the critical stress state may induce delayed brittle failure.

A major step in evaluating this concept involved an examination of the particular case of carbon (nitrogen) in steel. In the temperature-range 700–1,000° F. carbon has approximately the same mobility

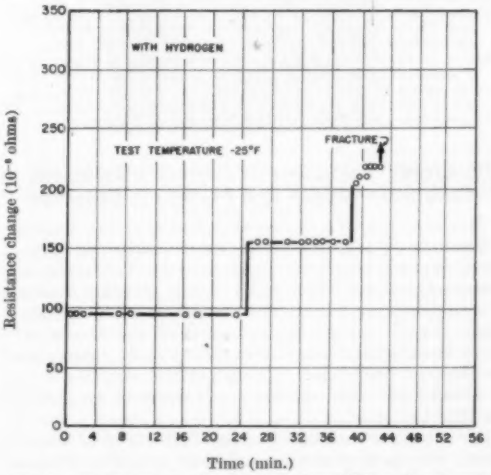


Fig. 1. Resistance vs. time in the delayed-failure stress range of a uniformly hydrogenated nickel–chromium–molybdenum steel

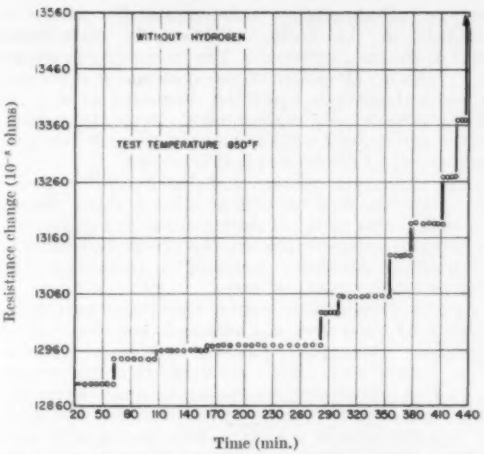


Fig. 2. Resistance vs. time in the delayed-failure stress range of a high-temperature die steel

in steel as has hydrogen at room temperature. Notched specimens of a high-temperature die steel (0·40 per cent carbon, 0·35 per cent manganese, 1·10 per cent silicon, 5·00 per cent chromium, 0·90 per cent vanadium, 1·35 per cent molybdenum) were subject to sustained-load-to-failure tests in the appropriate temperature-range. Resistance versus time measurements[3,4] were recorded during the sustained-load tests. All the significant features of time-dependent brittle failure were observed in an almost perfect image of the behaviour of hydrogen in steel (cf. Figs. 1 and 2). Fig. 2 vividly illustrates the incubation period and the step-like appearance associated with discontinuous crack propagation.

These results lend authority to the concept that interstitial-induced delayed brittle failure may be a general behaviour in metals which can attain the critical stress state in the temperature-range dictated by the mobility requirement. The implications derived from this work are far-reaching. They indicate that 'pressure in a void' is unnecessary to explain time-dependent brittle failure. In addition, they suggest the the possibility of unifying this behaviour with other, more familiar, phenomena which also are paced by the diffusion of interstitials, such as slow-strain-rate embrittlement and strain ageing[10].

T. E. Scott
A. R. Troiano

Case Institute of Technology,
University Circle,
Cleveland, 6,
Ohio.
Dec. 7.

[1] Petch, N. J., and Stables, P., *Nature*, **169**, 842 (1952).
[2] Frohmberg, R. P., Barnett, W. J., and Troiano, A. R., *Trans. Amer. Soc. Met.*, **47**, 892 (1955).
[3] Barnett, W. J., and Troiano, A. R., *Trans. Amer. Inst. Mining and Met. Eng.*, **209**, 486 (1957).
[4] Johnson, H. H., and Troiano, A. R., *Nature*, **179**, 777 (1957).
[5] Johnson, H. H., Morlet, J. G., and Troiano, A. R., *Trans. Amer. Inst. Mining and Met. Eng.*, **212**, 528 (1953).
[6] Troiano, A. R., *Corrosion*, **15**, 207 (1959).
[7] Klier, E. P., Muvdi, B. B., and Sachs, G., *J. Metals*, **9**, 106 (1957).
[8] Steigerwald, E. A., Schaller, F. W., and Troiano, A. R., *Trans. Amer. Inst. Mining and Met. Eng.*, **215**, 1048 (1959).
[9] Steigerwald, E. A., Schaller, F. W., and Troiano, A. R. (to be published).
[10] Troiano, A. R., 1959 Campbell Memorial Lecture, Amer. Soc. Met. (to be published).

Determination of Oxygen in Iron and Steel

We have recently applied the method of stable isotope dilution[1] to the determination of oxygen in samples of iron and steel which contained low concentrations of this element. As our results are consistently higher than values obtained by the conventional vacuum-fusion method, this preliminary account of our work is submitted.

The technique consists of allowing the steel sample to react with carbon at 1,500° C. in an atmosphere containing a known amount of carbon monoxide enriched in the isotope oxygen-18. Measurement of the ratio $R = {}^{18}O/{}^{16}O$ in a sample of the gas after equilibration enables the oxygen content of the metal to be determined. 'Blank' corrections are negligible, but as an additional precaution may be avoided by prior equilibration of the graphite crucible used as container for the sample in an atmosphere containing the same relative amounts of oxygen-18 and oxygen-16 as the expected final equilibrium value R.

Various methods have been used to determine the ratio R. At first, use was made of the mass spectrometer ion currents at $m/e = 30$ and 28 due to singly ionized $C^{18}O$ and $C^{16}O$ respectively. Here, however, it is necessary to apply a correction, based on the ion current at $m/e = 14$, to the value at $m/e = 28$, because nitrogen from the steel is always present in the gas mixture at the end of a dilution. A more accurate method is to convert part of the carbon monoxide in the equilibrated gas mixture to carbon dioxide, and to measure the ion currents at $m/e = 44$, 46 and 48. The value of R is then given by either $2h_{48}/h_{44}$ or by $(h_{48}/h_{44})^{\frac{1}{2}}$, where h_x represents the ion current at $m/e = x$. The three methods yield results which agree within experimental error. Instrumental errors are avoided by using the same method for both calibration and analysis.

Calibration is effected by admitting to the furnace small measured quantities of normal and enriched oxygen in proportions similar to those encountered in an analysis. Conversion of carbon monoxide to dioxide without isotopic dilution is achieved by compressing part of the gas mixture from the furnace into a small circulatory system which contains a platinum filament heated to 900° C. and a trap cooled in liquid air. By this means the equilibrium :

$$2CO \rightleftharpoons CO_2 + C$$

is constantly displaced until sufficient carbon dioxide has been formed for analysis.

Table 1 summarizes the calibration and analytical results for a standard steel sample, designated *BPL*-21, supplied by the British Iron and Steel Research Association. The mean oxygen content of this steel as determined by several independent investigators with the vacuum-fusion method is given as 0·003 per cent, with an overall range of 0·002–0·004 per cent for individual determinations. Our values are thus higher by a factor of about two. The scatter between individual analyses is not improved.

It is estimated that the combined sources of error in the above analyses should not exceed ± 25 per cent for any single determination. In the analysis of several iron–carbon alloys prepared in this laboratory, results have been duplicated to within 10 per cent in the range 0·006–0·011 per cent oxygen. These figures were again higher than the corresponding vacuum-fusion results by a factor of two to four. The good reproducibility obtained with specimens

Table 1. Isotope Dilution Analysis of Sample *BPL*-21

Sample No.	Weight of sample (gm.)	Volume of enriched oxygen (ml. at N.T.P.)	Volume of normal oxygen used for calibration (ml. at N.T.P.)	$R = {}^{18}O/{}^{16}O$ $(= 2h_{34}/h_{32})$	Oxygen-18 in enriched gas before dilution (per cent)	Oxygen in sample (per cent)
1	—	0·866	0·634	1·108	90·92	
	5·192	0·716	—	2·320		0·0061
2	—	0·944	0·599	1·200	89·07	
	7·725	0·584	—	1·500		0·0054
3	—	0·658	0·444	1·072	86·52	
	4·178	0·549	—	1·875		0·0063
4	—	0·865	0·589	1·143	89·57	
	4·033	0·478	—	1·311		0·0100
5	—	0·762	0·550	0·932	82·98	
	7·466	0·570	—	0·996		0·0074
					Mean	0·0070

prepared in the laboratory suggests that a large part of the scatter experienced with the British Iron and Steel Research Association standard may be due to inhomogeneities in the sample.

Steels containing manganese may be analysed by this technique if care is taken to introduce the enriched oxygen before the steel sample is dropped into the furnace. This precaution is necessary due to the rapidity with which the ferro-manganese film, which forms on the cold wall of the furnace, reacts with molecular oxygen. Analysis of a British Iron and Steel Research Association standard, designated *BNL*-21, which contained 0·44 per cent manganese, yielded a preliminary value of 0·0196 per cent for the oxygen content. This may be compared with the mean value of 0·0145 per cent reported for this steel by investigators using the vacuum-fusion technique.

Other work in progress in this Laboratory suggests that low results may be obtained for both oxygen and nitrogen by the vacuum-fusion method when the concentration of either of these elements is of the order of 0·01 per cent or less. If this is true, some revision of present accepted thermodynamic data may be necessary for alloys in this range of composition.

A full account of this work will be published elsewhere.

M. L. Pearce
C. R. Masson

Atlantic Regional Laboratory,
National Research Council,
Halifax, Nova Scotia.

[1] Kirshenbaum, A. D., and Grosse, A. V., *Trans. Amer. Soc. Metals*, **45**, 758 (1953); *Anal. Chem.*, **26**, 1955 (1954). Kirshenbaum, A. D., Mossman, R. A., and Grosse, A. V., *Trans. Amer. Soc. Metals*, **46**, 525 (1954). Inghram, M. G., "Ann. Rev. Nucl. Sci.", **4**, 81 (1954).

MINERALOGY

Determination of Tetrahedral Aluminium in Mica by Infra-Red Absorption Analysis

Continuation of studies[1] relating the infra-red absorption spectra and the aluminium substitution for silicon in the chlorite minerals has shown that a similar correlation exists in almost all micas. Regardless of the species under study (that is, muscovite, lepidolite, biotite, phlogopite), the shape of the 9–10μ region of the absorption spectra depicts the amount of aluminium substitution for silicon (Y number) in the basal, tetrahedrally co-ordinated level in the mica structure. The micas may be natural or synthetic. Position of the maxima of absorption is again dependent upon the dominant type of ion in the octahedrally co-ordinated level, the maxima shifting to slightly longer wave-length with increasing atomic weight of the ions in this position.

The aluminium content and distribution in a mica, therefore, can now be estimated by a rapid physical method. This is in marked contrast to experiences of previous workers[2] who have had great difficulty with differential solubility methods in estimating the aluminium in micas and clays.

In the dioctahedral micas, the aluminium in the octahedral level does not influence the shape of the infra-red absorption pattern, although, because of its lighter mass effect, the position of the maxima is shifted to shorter wave-lengths than with iron- and magnesium-bearing trioctahedral analogues. At first thought, it is strange that such a correlation should exist between Y number and absorption spectra, regardless of the mica species present. The tetrahedrally co-ordinated basal level in the mica structure, however, is common to all species; the ions differentiating the species from one another appearing in the octahedral and interlayer positions.

By the courtesy of people too numerous to mention in this short note, who have kindly sent us samples, we have been enabled to include the infra-red absorption curves of 22 analysed micas (Figs. 1 and 2). Members of the same mica species are listed in the vertical columns of curves, in order of decreasing Y number, so that horizontal comparison between micas with the same degree of aluminium substitution may be readily made. One of the muscovites and three of the biotites are not yet analysed, but

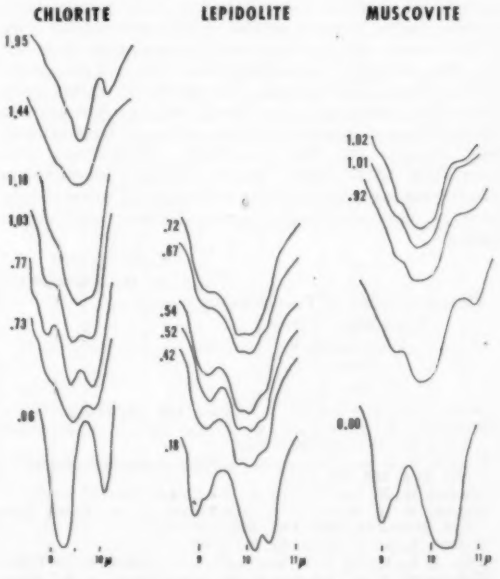


Fig. 1. Centre section (8·5–11μ) of infra-red absorption curves arranged in order of decreasing aluminium substitution for silicon (Y number). Curves in each species column are displaced vertically. Micas with equivalent Y number may be compared horizontally. Missing number for the muscovite curve is awaiting completion of chemical analysis

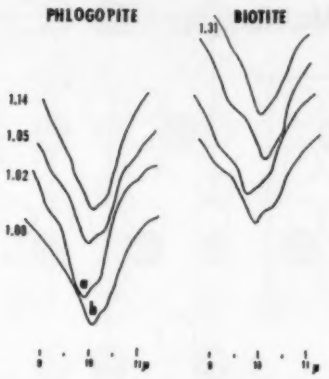


Fig. 2. Centre section (8·5–11μ) of infra-red absorption curves for the phlogopite and biotite series. Arrangement as for Fig. 1. Phlogopite curves (*a*) and (*b*) have same Y number but are displaced laterally 0·2μ. Curve (*a*) is a magnesian phlogopite whereas (*b*) has a 1/3 iron substitution. Three of the biotites are not analysed at the present time

have been placed in relative position as deduced from the shape of their curves.

As with the chlorite series, the pure tetrasilicic end member ($Y=0$) (of at least the muscovite and lepidolite series) has a complex absorption pattern in the 9–10μ region. In addition to the normal broad absorption (or doublet) at 10·1–10·4μ, a pronounced doublet appears between 8·85 and 9·04μ. With increasing aluminium substitution, as Y rises from 0·4 towards 0·6, this doublet between 9·8 and 10·3μ becomes a triplet, with the short wave-length peak of this triplet becoming dominant as Y values increase above 0·9. The doublet at 9μ gradually fades out as Y increases towards unity, leaving the simplified, single absorption at 9·7–9·8μ.

Only one mica sample with Y value greater than 1·2 could be obtained. It may be that this value of 1·2 is again as critical in the broad groups of micas as it was in the chlorites[1], marking some type of structural change.

Difficulty has been experienced in relating the minerals talc and pyrophyllite to this scheme. Both possess effectively a zero aluminium substitution ($Y=0$), but their absorption spectra, which are very similar in pattern, consist of simple, single absorptions, suggesting a $Y=2$ situation as in the chlorite series. In addition, margarite, with a $Y=2$, has an unusually complex pattern and is markedly displaced to higher wave-lengths, compared with the septeamesite ($Y=2$) of the chlorite study.

It would be expected that the montmorillonite groups would show a similar correlation between Y number and infra-red absorption, although their lower degree of crystallinity would make the individual absorptions less distinct. Investigation of all these points is actively progressing.

R. J. P. Lyon

Stanford Research Institute,
Menlo Park, California.

W. M. Tuddenham

Kennecott Research Center,
Kennecott Copper Corporation,
Salk Lake City, Utah.

October 1.

[1] Tuddenham, W. M., and Lyon, R. J. P., *Anal. Chem.*, **31**, 377 (1959).
[2] Yoder, H. S., in "Clays and Clay Minerals", Monograph No. 2 (Pergamon Press, New York, 1959).

CHEMISTRY

The α- and β-Forms of Calcium Sulphate Hemihydrate

Kelley, Southard and Anderson[1] have shown that the thermodynamic properties of calcium sulphate hemihydrate depend on whether the hemihydrate is produced from gypsum calcined in a steam-saturated atmosphere (α-hemihydrate), or under conditions where the partial pressure of water vapour is low (β-hemihydrate), but the nature of a hemihydrate prepared under conditions intermediate between these two extremes (for example, the manufacture of gypsum plaster by the kettle process) is not known for certain. These authors considered that such a hemihydrate would consist of a mixture of the α- and β-forms, but Eipeltauer[2] considered that there would also be some hemihydrate crystals having properties intermediate between these two forms. Work that I have done shows that only the α- and β-hemihydrates can be detected by differential thermal analysis in a sample of hemihydrate prepared by calcining gypsum under conditions simulating the manufacture of gypsum plaster in a kettle.

By means of differential thermal analysis it is possible to detect in a sample of calcium sulphate hemihydrate the various forms the rates of transformation from soluble to insoluble anhydrite of which vary[3], since each phase-change is shown by an exothermic peak at a particular temperature on the differential thermal curve. A sample of hemihydrate was prepared by heating 800 gm. of a washed natural gypsum for 5 hr. in a glass container filled to a depth of 3 in. (oven temp. 170° C.). The sample was cooled and then dried at 50° C., and the water content determined as 6·05 per cent (theoretical 6·21 per cent). The differential thermal curve for a partly dehydrated sample of this hemihydrate is shown in Fig. 1, curve *a*. The water content of the sample was reduced to about 1 per cent by heating for 1 hr. at 120° C., otherwise the exotherm shown at about 245° C. was completely absorbed in the large endotherm due to the loss of water from hemihydrate. After heating at 120° C. duplicate samples were allowed to rehydrate at 65 per cent relative humidity; resultant changes in weight indicated that the amount of insoluble anhydrite formed at 120° C. was very small. The exotherm shown at 245° C. on curve *a*

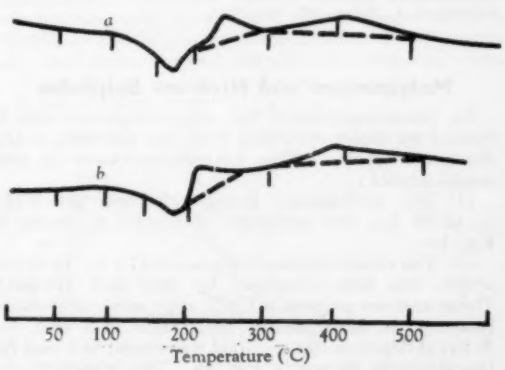


Fig. 1. Differential thermal analysis curves for calcium sulphate hemihydrate (water content 1 per cent). *a*, a hemihydrate prepared under conditions simulating manufacture of gypsum plaster by the kettle process. *b*, a mixture of 70 per cent α-hemihydrate and 30 per cent β-hemihydrate

appears to be complete before the second exothermic reaction commences at about 300° C., and there is no indication of the decomposition of a phase intermediate between these two. The size and shape of the two exothermic peaks on curve *a* are very similar to those shown on curve *b*, which was obtained from a mixture of 70 per cent of α-hemihydrate, prepared by autoclaving, and 30 per cent β-hemihydrate. For comparison, the water content of this sample was also reduced to about 1 per cent prior to differential thermal analysis. The peak temperatures of the two exotherms on curve *a* occur at slightly higher temperatures than those on curve *b*, and the exotherm at 210° C. on the latter curve appears to commence before the small endotherm due to the loss of about 1 per cent water is complete.

The differential thermal analysis of a hemihydrate prepared as described above shows the presence of two main phases only, and by this technique it was not possible to detect a phase intermediate between the two. However, since the peak temperatures of the two exotherms on curve *a* occur at slightly higher temperatures than those for the mechanical mixture (curve *b*), this may indicate slight differences between different preparations of both α- and β-hemihydrates.

In general it was found that the proportion of each phase shown on the differential thermal curve could be determined more accurately from the area beneath the β-exotherm, because any insoluble anhydrite that might form during the preparation of a sample would be produced mainly from the more reactive α-phase. Since it has been shown that the α-exotherm is due only to the first rapid part of the transformation of α-soluble anhydrite to insoluble anhydrite[3] (the latter part of the reaction is slow and is not recorded by differential thermal analysis) the formation of small amounts of insoluble anhydrite prior to differential thermal analysis can greatly reduce the size of the α-exotherm.

D. A. Powell

Division of Building Research,
Commonwealth Scientific and Industrial
Research Organization,
Graham Road, Highett,
Victoria, Australia.
Nov. 12.

[1] Kelley, K. K., Southard, J. C., and Anderson, C. T., U.S. Bur. Mines Tech. Paper 625 (1941).
[2] Eipeltauer, E., *Zement-Kalk-Gips*, **9**, 501 (1956).
[3] Powell, D. A., *Nature*, **182**, 792 (1958).

Molybdenum and Niobium Sulphides

In the system Mo-S the only compound that is formed by direct synthesis from the elements is the disulphide MoS_2. This compound exists in two modifications :

(1) The well-known hexagonal form ($a=3{\cdot}16$; $c=12{\cdot}29$ A.), the structure of which[1] is shown in Fig. 1*a*.

(2) The rhombohedral form ($a=3{\cdot}17$; $c=18{\cdot}38$ A.) which was first described by Bell and Herfert[2]. These authors propose a $CdCl_2$-type structure which, however, is incompatible with their own and our X-ray diffraction data. Good agreement is found for the structure shown in Fig. 1*b*. This structure can be described in space-group $R3m$—C^5_{3v} : 3 Mo situated in 3(*a*) : 0 0 *z*, etc., with $z=0$; 3 S I in 3(*a*) with $z\approx\frac{1}{4}$ and 3 S II in 3(*a*) with $z\approx5/12$.

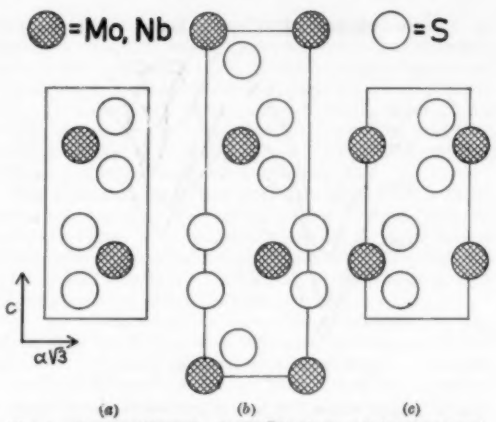


Fig. 1. Sections [through the (11$\bar{2}$0) planes of (*a*) hexagonal MoS_2, (*b*) rhombohedral MoS_2 and NbS_2, (*c*) hexagonal NbS_2

In both forms of MoS_2 the metal environment is trigonal prismatic. In synthetic molybdenum disulphides generally a considerable degree of stacking disorder in the *c* direction is present which causes a weakening of the reflexions with $h-k\neq3n$, increasing with increasing value of *l*.

In the system Nb-S the following phases are observed :

(1) Monoclinic NbS_2 ($a=4{\cdot}94$; $b=6{\cdot}74$; $c=18{\cdot}1$ A. ; $\beta=97{\cdot}5°$), which is probably isotypic with TiS_2 [3] and $ZrSe_2$ [4].

(2) Rhombohedral NbS_2 ($a=3{\cdot}33$; $c=17{\cdot}81$ A.), stable below about 800° C. This phase is probably identical with the disulphide found by Hägg and Schönberg[5], for which they propose a $CdCl_2$-type structure. This structure type, however, is in conflict with our intensity data ; the structure we derive is isotypic with rhombohedral MoS_2 (Fig. 1*b*). Generally, stacking disorder in the *c* direction is observed ; it can be diminished by annealing at 700–800° C.

(3) Hexagonal NbS_2 ($a=3{\cdot}31$; $c=11{\cdot}89$A.) is formed from the elements above 850° C. and is stable up to 1,050° C. The space group is $P6_3/mmc$—D^4_{6h}, the same as in the case of hexagonal MoS_2, but the structure is different. 4 S lie in 4(*f*) : $\pm(\frac{1}{3}, \frac{2}{3}, z$; $\frac{1}{3}, \frac{2}{3}, \frac{1}{2}-z)$ with $z\approx\frac{1}{8}$; 2 Nb either in trigonal prismatic holes 2(*b*) : $\pm(0\,0\,\frac{1}{4})$ or in octahedral holes 2(*a*) : 0 0 0 ; 0 0 $\frac{1}{2}$. X-ray diffraction can scarcely distinguish between these two arrangements, which are exactly homometric if $z_8=\frac{1}{8}$. Because of the analogy with rhombohedral NbS_2 and because of stacking arguments, position 2(*b*) is preferred (Fig. 1*c*). Once more, stacking disorder in the *c* direction is found.

(4) Rhombohedral $Nb_{1+x}S_2$ ($a=3{\cdot}33$; $c=17{\cdot}80$–$17{\cdot}85$ A.), the range of homogeneity of which stretches from $x\approx0{\cdot}12$ to $x\approx0{\cdot}25$ at 1,100° C. and to $x\approx0{\cdot}5$ at 800° C. The structure which is shown in Fig. 2*a* can be described in space group $R3m$—C^5_{3v} : 3 Nb I in 3(*a*) : 0 0 *z*, etc., with $z=0$; 3*x* Nb II in 3(*a*) with $z\approx5/6$; 3 S I in 3(*a*) with $z\approx\frac{1}{4}$; 3 S II in 3(*a*) with $z\approx5/12$. The co-ordination of Nb I is trigonal prismatic, that of Nb II octahedral. Here, stacking disorder is inhibited by the presence of Nb II between the layers.

(5) Hexagonal $Nb_{1+x}S_2$ ($a=3{\cdot}31$; $c=12{\cdot}53$–$12{\cdot}65$ A.) is stable above about 1,000° C. in the range $x\approx0{\cdot}30$ to $x\approx0{\cdot}43$. The space group is $P6_3/mmc$—D^4_{6h} ; 2 Nb I are situated in 2(*b*) : $\pm(0\,0\,\frac{1}{4})$; 2*x*

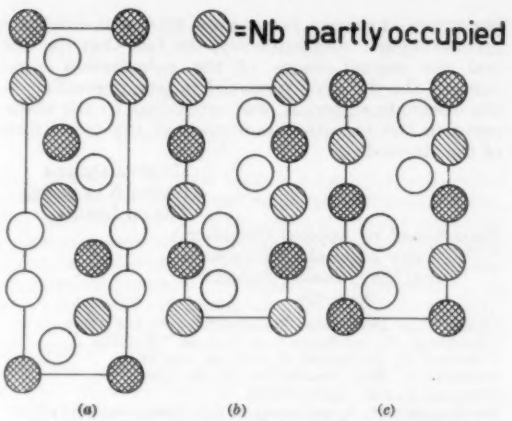


Fig. 2. Sections through the (11$\bar{2}$0) planes of (*a*) rhombohedral $Nb_{1+x}S_2$, (*b*) hexagonal $Nb_{1+x}S_2$, (*c*) one of the possible arrangements of $Nb_{1-y}S_2$

Nb II in 2(*a*) : 0 0 0 ; 0 0 $\frac{1}{2}$ and 4 S in 4(*f*) : $\pm(\frac{1}{3}, \frac{2}{3}, z$; $\frac{1}{3}, \frac{2}{3}, \frac{1}{2}-z)$ with $z \approx \frac{1}{8}$. This structure (Fig. 2*b*) seems more likely than the homometric arrangement with interchanged Nb I and Nb II positions, the reasoning being the same as in the case of hexagonal NbS_2. Again, stacking disorder is prevented by the presence of Nb II.

(6) Hexagonal $Nb_{2-y}S_2$ is stable below about 850° C. in the range $y \approx 0{\cdot}0$ to $y \approx 0{\cdot}3$. The X-ray patterns closely resemble those of hexagonal $Nb_{1+x}S_2$ and, therefore, the structure is either analogous to that of hexagonal $Nb_{1+x}S_2$ (Fig. 2*b*) with statistical vacancies in the 2(*a*) site, or to its homometric form with the vacancies in the 2(*b*) position (Fig. 2*c*). The possibility that hexagonal $Nb_{1+x}S_2$ and $Nb_{2-y}S_2$ belong to the same homogeneity range cannot be excluded. $Nb_{2-y}S_2$ is probably identical with the phase NbS described by Hägg and Schönberg[5]. These authors propose an NiAs-type structure for NbS with an excess of sulphur ($a = 3{\cdot}32$; $c = 6{\cdot}46$ A.) and a WC-type structure for NbS in equilibrium with Nb ($a = 3{\cdot}32$; $c = 3{\cdot}23$ A.). Evidently, Hägg and Schönberg overlooked the reflexions with $l \neq 2n$ which have rather weak intensities ; for $y = 0$ the intensities of the reflexions with $l = 4n + 2$ become zero. Therefore, the c axes found by Hägg and Schönberg[5] are one-half and one-quarter of the actual one respectively.

(7) Above 850° C. one or more phases occur at compositions about NbS. The relationships in this range are rather complicated and not yet fully understood.

Details of these investigations will be reported elsewhere.

F. JELLINEK

Anorganisch-chemisch Laboratorium,
Rijksuniversiteit Groningen,
Netherlands.

G. BRAUER
H. MÜLLER

Chemisches Laboratorium der Universität,
Freiburg i. Br., Germany.

Oct. 27.

[1] Dickinson, R. G., and Pauling, L., *J. Amer. Chem. Soc.*, **45**, 1465 (1923).
[2] Bell, R. E., and Herfert, R. E., *J. Amer. Chem. Soc.*, **79**, 3351 (1957).
[3] Hahn, H., and Harder, B., *Z. anorg. Chem.*, **288**, 241 (1956).
[4] Krönert, W., and Plieth, K., *Naturwiss.*, **45**, 416 (1958).
[5] Hägg, G., and Schönberg, N., *Arkiv Kemi*, **7**, 371 (1954).

Oscillographic Investigation of Electrodeposition of Chromium

A GREAT deal of work on the theory of electrodeposition of chromium has been carried out since 1920. E. Müller[1] reported the formation of chromium chromate film on the cathode surface and inferred the mechanism of chromium electrodeposition from the polarization phenomena. Recently D. Reinkowski and C. A. Knorr[2] fully examined the reproducibility of the cathode-polarization curves, and presented a new view of the existence of their different potential range and on the transition between these ranges. More recently, H. Gerischer and N. Käppel[3] postulated another theory of the chromic oxide film formed on the cathode surface, measuring the quasi-stationary potential-current curves using a potentiostatic method.

In the present communication, the charging curves during cathodic polarization at various current densities in the solution containing mainly 3 *M* CrO_3 were measured by the oscillographic method devised by A. Hickling[4]. The electrolytes used in this experiment were as follows : (*a*) 3*M* CrO_3, (*b*) 3 *M* CrO_3, 0·03 *M* sulphuric acid. The electrolytic temperature was always kept at 20° C. The charging curves at the platinum and gold electrodes during cathodic polarization at various current densities in the solution (*b*) are shown in Figs. 1*A* and 2*A*, respectively. The schematic representations of these curves at 20 amp./sq. dm. are shown in Figs. 1*B* and 2*B* respectively. The ordinates represent the potentials vs. *S.C.E.* and the abscissæ are proportional to the quantities of electricity passed. In solution (*a*), at all current densities the charging curves were the same tracks as those obtained in the solution (*b*) at 20 amp./sq. dm.

The tracks of the charging curves at 20 amp./sq. dm. in solution (*b*) passed through four inflexion points (1, 2, 3 and 4 from positive potentials to negative), and reached the constant potentials, forming the three stages (*a*, *b* and *c*), as shown in Figs. 1*B* and 2*B*.

In comparison with the current-potential curves in solution (*b*) at both electrodes (see Figs. 5 and 7 of ref. 2), which consisted of four or three different potential-ranges, it may be noted that the inflexion points (2) (+192 mV. at the platinum electrode, +674 mV. at the gold electrode) approximately correspond to the ends of the first stages of the polarization curves, in the same manner (3) (−268 mV. (platinum) +296 mV. (gold)) to the ends of the second stages, (4) (−412 mV. (platinum), −780 mV. (gold)) to the beginning of the third or fourth stages. At the lower current densities (5 amp./sq. dm.,

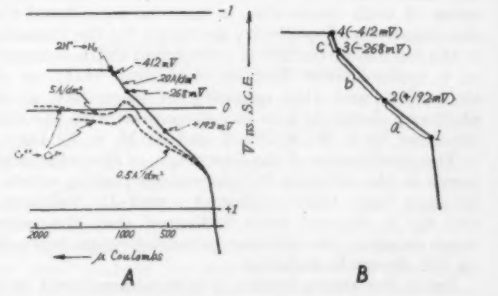


Fig. 1. *A*, Charging curves of the platinum electrode during cathodic polarization in the solution (*b*) at various current densities ; *B*, schematic representation of Fig. 1 at 20 amp./sq. dm.

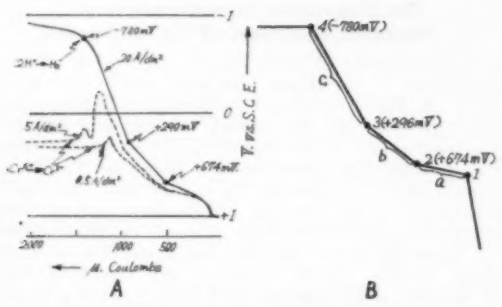


Fig. 2. *A*, The charging curves of the gold electrode during cathodic polarization in the solution (*b*) at various current densities ; *B*, the schematic representation of Fig. 2 at 20 amp./sq dm.

0·5 amp./sq. dm.) in solution (*b*) the tracks of the oscillograms did not reach the inflexion points (4), but gave constant potentials at the inflexion points (3) or (2). At these potentials only the reduction process of Cr^{6+} to Cr^{3+} occurred.

A. Hickling[4,5] and S. E. S. El Wakkad *et al.*[6,7] studied the reduction of the oxide films of platinum and gold electrodes, measuring the charging curves of these electrodes during cathodic polarization. In comparison with their results (see Fig. 9 of ref. 6 and Plate II, I of ref. 5), it is seen that the stages (*a*) in Figs. 1 and 2 correspond to those of the reduction processes of PtO and Au_2O_3, respectively. F. Baumann and I. Shain[8] found that the reduction process of Cr^{6+} to Cr^{3+} occurred soon after the reduction of the oxide film of the gold electrode, using a gold rotating electrode. Consequently, it is considered that at stage (*a*) the reduction of the oxide films of these electrodes occurs.

From the fact that the stage (*b*) exhibited the same slope at both electrodes, that is, platinum and gold, it is suggested that the same electrode reaction occurs. The inflexion points (3) corresponded to the ends of the second stages on the polarization curves, and at the ends of these stages the electrodes should be fully covered with chromium chromate film. Therefore, it is considered that stage (*b*) exhibits the quantity of electricity required for the formation of this film. The number of ions of Cr^{3+} formed on the stage (*b*) were evaluated from the quantity of the electricity : at the platinum and gold electrodes these are $1{\cdot}00\times10^{15}$ ions/sq. cm. and $1{\cdot}37\times10^{15}$ ions/sq. cm., respectively. The number of atoms of platinum and gold per sq. cm. at the platinum and gold surfaces are, respectively, $1{\cdot}61\times10^{15}$ atoms/sq. cm. and $1{\cdot}50\times10^{15}$ atoms/sq. cm. Considering the uncertainty of the exact values of the surface areas of both electrodes, it may be considered that the quantities of electricity necessary for the formation of the films approximately correspond to the formation of a unimolecular film of chromium (III) on the electrodes, and this quantity of electricity at the platinum electrode is in fair agreement with the value obtained by I. M. Kolthoff and A. M. S. El Din[9].

The significance of the four stages of the polarization curve in the solution (*b*) (chromium plating solution) has not been fully explained ; and D. Reinkowski and C. A. Knorr[2] have indicated that the second stage exists in the different potential range depending on the electrode material.

From the above results, it is considered that at the first stage of the polarization curve the reduction of the oxide film of the electrode occurs in the case of platinum and gold electrodes, and that the film of chromium chromate forms soon after this reduction process occurs. Consequently, the fact that the first and the second stages of the polarization curve exist at the different potential ranges, depending on the electrode materials, was attributed to the differences in the reduction potentials of the oxide films of the electrodes.

Hideya Okada
Kenji Nakamura
Takeo Ishida

Department of Applied Chemistry,
University of Osaka Prefecture,
Sakai City, Osaka, Japan.
Sept. 28.

[1] Müller, E., *Z. Elektrochem.*, **32**, 399 (1926) ; **50**, 172 (1944).
[2] Reinkowski, D., and Knorr, C. A., *ibid.*, **58**, 709 (1954).
[3] Gerischer, H., and Käppel, M., *ibid.*, **61**, 463 (1957).
[4] Hickling, A., *Trans. Faraday Soc.*, **41**, 333 (1945).
[5] Hickling, A., *ibid.*, **42**, 518 (1946).
[6] El Wakkad, S. E. S., and Emara, S. H., *J. Chem. Soc.*, 461 (1952).
[7] El Wakkad, S. E. S., and Emara, S. H., *ibid.*, 3098 (1954).
[8] Baumann, F., and Shain, I., *Anal. Chem.*, **29**, 303 (1957).
[9] Kolthoff, I. M., and El Din, A. M. S., *J. Phys. Chem.*, **60**, 1564 (1956).

A Synergic Method of carrying out Continuous Electrochromatography

Although some workers using the technique of continuous electrochromatography on conventional anticonvection media (such as filter paper or glass powder) have supposed that specific adsorption effects play a part in the separation, the extent to which these can in fact influence the separation, if at all, is negligible. The adsorbed Stern layer ions are practically immobile with respect to both electrophoretic and hydrodynamic gradients ; thus even notionally, since each is equally affected, the resultant of motion in the two mutually perpendicular directions should be independent of the degree of adsorption. Weber[1] has considered the general differential equation describing the concentration distribution (as a function of space and time) in terms of diffusion, adsorption, and the two velocities, on the assumption that adsorption equilibrium is reached instantaneously. The solution of this equation for the stationary state does not involve an adsorption term.

It seems likely that improved electrochromatographic separations might be achieved by substituting ion-exchange membrane 'curtains' for paper ones. In this way a stationary phase capable of highly selective sorption could be provided, within which particles would be immobilized with respect to eluant flow but not with respect to current flow. Consequently the change brought about in mobility ratios might be expected to differ from that brought about in retention-volume ratios ; and in certain systems at least the direction of these changes might be such as to give rise to synergy between electrophoresis and chromatography. An analysis of the situation shows that this expectation is well founded. If we define a 'separation coefficient' $D^1{}_2$ as the ratio $\tan\theta_1/\tan\theta_2$, where θ is the angle through which the path of a given species is swept from the vertical under the influence of an applied potential, then the following relations can be derived :

Ion-exchange resin absent :

$$D^1{}_2 = \frac{u_1}{u_2} \cdot \frac{\rho^0{}_2}{\rho^0{}_1} \qquad (1)$$

Ion-exchange resin present (volume of eluant per gm. resin small) :

$$D^1{}_2 = \underbrace{\frac{\bar{u}_1}{\bar{u}_2}}_{\text{electrophoretic factor}} \cdot \underbrace{\frac{\rho^r{}_2}{\rho^r{}_1} \cdot \frac{K^0{}_1}{K^0{}_2}}_{\text{chromatographic factor}} \qquad (2)$$

The first term in each case is a ratio of mobilities, measured in the free eluant in (1) and in the resin in (2). The third term in (2) is the ratio of specific retention volumes, measured in the *absence* of any complexing agent in the eluant. The second term arises from the possible presence of a ligand. The quantity ρ_i is the ratio (total concentration of species i in eluant)/(concentration of uncomplexed species i in eluant), and depends on the concentrations of both i and ligand as well as *p*H. The superscripts denote presence or absence of ion-exchange resin, since this factor is altered by the equilibria displacements resulting from the introduction of resin. In the derivation it is assumed that the mobility of the complexed species is negligibly small in comparison with that of the uncomplexed species, that diffusion can be neglected and exchange equilibria regarded as instantaneous, and that the resin is lightly loaded.

Comparison of equations (1) and (2) shows at a glance why synergy arises when an ion-exchanger is introduced into the system. In general one can say, for a series of like ions, that the greater the mobility of an ion the greater its affinity for an ion-exchange resin and the lower the stability of its complexes[2]. Furthermore it can be shown that the 'complexone affinity' term in equation (2) is very much further from unity than that in equation (1) for a given total concentration of complexone, unless vanishingly small quantities of material are to be separated. (In the absence of complexone it is, of course, unity.) This is an important effect *per se*.

A suitable arrangement for separations of this kind consists of a pack of ion-exchange membranes interleaved with filter paper or similar material to act as flow stabilizer. This has the advantage over a trough filled with fine resin granules in that it is relatively easy to obtain uniform flow. Moreover, membranes of high selectivity are likely to become more readily available than their granular counterparts. For a given system the coefficient $D^1{}_2$ can be evaluated most simply by carrying out separate electrophoretic and chromatographic separations on strips of paper or paper–membrane–paper sandwich. Such strips are readily examined spectrophotometrically or radiometrically, and it is only necessary to divide the ratio x_1/x_2 of distances moved in an electrophoretic run by the corresponding ratio for a chromatographic run carried out under the same conditions. Runs have been performed on single strips of sulphonated polyvinyl chloride membrane[3] 3 cm. wide and 30–45 cm. long sandwiched between two strips of 'Separa *DHC*' paper (W. and R. Balston, Ltd.) of the same width. For convenience the system sodium-22 (2·6 yr.)–potassium-42 (12·4 hr.) was chosen for study. The membranes were used in the dimethylammonium form; the eluant (electrolyte) contained uramil-N,N-diacetic acid and dimethylamine, its *p*H being determined by the concentration of the latter. Similar conditions have been employed successfully to resolve mixtures of alkali ions on ordinary ion-exchange columns[4]. The electrophoretic runs required about 0·04 ampere-hours at 750 volts.

The results obtained in a series of experiments with the membrane are compared with those for paper alone in Fig. 1. The strips were loaded with 0·5 μmole of each ion. It is seen that although the mobility ratio is somewhat decreased in the presence of membrane its *p*H dependence parallels the behaviour in the absence of membrane. On the other hand the corresponding chromatographic ratio, in the presence of membrane, undergoes a sharp decrease between *p*H 8 and 9. This can be traced to the operation of the complexone affinity term in equation (2). Although in this system the membrane itself exhibits no noticeable preference, the synergic influence of the chromatographic component in its presence is evident.

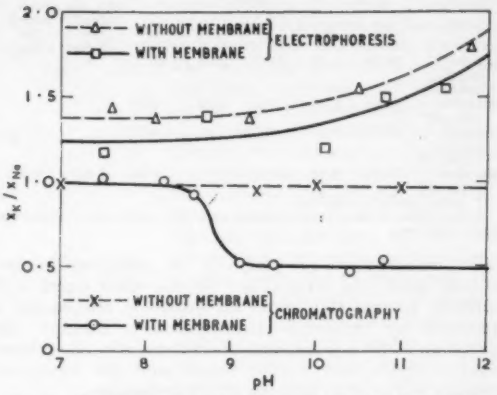


Fig. 1. Evaluation of a system by means of strip experiments

A full account of this work, including a comparison of several membranes and a description of a working cell used for the separation of lithium, sodium and potassium, is in preparation.

Acknowledgement is gratefully made to Mr. T. A. Gough for technical assistance. This note forms the substance of Brit. Pat. Appl. No. 39033/58, and is published by permission of the National Research Development Corporation and the Director, National Chemical Laboratory.

S. R. Caplan

National Chemical Laboratory,
Department of Scientific and Industrial Research,
Teddington, Middlesex. Nov. 16.

[1] Weber, R., *Helv. Chim. Acta*, **36**, 424 (1953).
[2] Reichenberg, D., and McCauley, D. J., *J. Chem. Soc.*, 2741 (1955). Reichenberg, D., *Chem. Technik*, **10**, 454 (1958).
[3] Hookway, H. T., Hale, D. K., and Goldsmith, R. G., Brit. Pat. Appl. 336 (1957).
[4] Buser, W., *Helv. Chim. Acta*, **34**, 1635 (1951).

Reduction of Graphite by Lithium-Ethylenediamine

It is well known that coals can be converted to liquid fuels by catalytic hydrogenation at high temperatures and pressures. However, coals of high rank (>89 per cent carbon m.a.f.) are liquefied in poor yield[1]; anthracites (>92 per cent carbon m.a.f.) are very difficult to hydrogenate; and graphite cannot be hydrogenated to liquid or solid products.

Recent work in this laboratory[2] has shown that coals and vitrains containing up to 92 per cent carbon can be reduced by the lithium-ethylenediamine system[3]; hydrogen is added, no carbon–carbon bonds are broken, and the reaction takes place under the mild conditions of 115° and atmospheric pressure.

Table 1

	C	H	N	Ash	O (diff.)	gm. H_2 added per 100 gm.	gm. H_2O added per 100 gm.
Graphite, starting material*	98·90	0·29	0·07	0·87	−0·13		
Graphite, reduced*	85·39	2·91	3·83	6·28	1·59		
Graphite, starting material†	99·79	0·29	0·07	—	−0·15		
Graphite, reduced†	95·95	2·12	0·07	—	1·86	1·65	2·35

* Actual analytical values.
† Analytical values corrected to a moisture-, ash- and ethylenediamine-free basis.

The insolubility of graphite in ethylenediamine should hinder its reduction; on the other hand, it is already known that even an insoluble anthracite is reduced by lithium-ethylenediamine; further, the graphite structure consists almost entirely of carbon–carbon single and double bonds, and the latter are readily reduced by lithium-ethylenediamine.

Three gm. of Madagascar flaky graphite (previously de-ashed by treatment with hydrofluoric acid) was reduced with 6·80 gm. of lithium and 150 ml. of ethylenediamine[2]. The recovered material weighed 3·11 gm. Table 1 gives the analytical values for the product. The graphite after reduction retains nitrogen, probably in the form of chemically combined ethylenediamine; this is the same behaviour found with coal. A correction must be made for this combined ethylenediamine, since it contains hydrogen. Table 1 gives the analytical composition of the graphite, corrected to a moisture-, ash-, and ethylenediamine-free basis. The value of 1·65 gm. of hydrogen added per 100 gm. of starting graphite seems remarkably high, particularly when the mildness of the conditions used is considered. This value of 1·65 gm. corresponds to addition of 19·7 atoms of hydrogen per 100 carbon atoms in the original graphite. This is much lower than the value of 44·8 atoms of hydrogen per 100 carbon atoms found for a high-rank bituminous vitrain[2] (90·4 per cent carbon m.a.f.), but it compares favourably with the value of 16·9 found for an anthracite[2].

To determine the effect of the treatment on the graphite lattice, X-ray diffraction patterns of the treated sample were examined. The patterns of the untreated and treated graphite (Fig. 1) were obtained from compressed slab specimens by the reflexion method. The (002) band of the treated sample was greatly decreased (not obvious on Fig. 1) and broadened and has a peculiar shape. Furthermore, a distinct band has been formed at a d-spacing of 4·82 A. Lithium is known to form interstitial compounds with graphite. The reduced sample was analysed and found to contain 1·5 per cent lithium. To decrease the lithium content, the sample was treated with hydrochloric acid and washed. It then contained 0·47 per cent lithium. The X-ray patterns of the sample before and after this treatment were identical; that is, the (002) and 4·82 A. bands were not affected. The large amount of nitrogen present is somewhat disturbing; however, it appears that hydrogen atoms have been added to the graphite lattice to produce hydrogenated layers. The average distance between parallel adjacent alicyclic units is estimated to be 4·7–4·9 A.

X-ray examination of the compressed slab specimen by the transmission method revealed that the (*hkl*) reflexions were also reduced and broadened. This suggests that treatment of graphite flakes with lithium-ethylenediamine effectively reduces the size of crystals, in particular the stacking height.

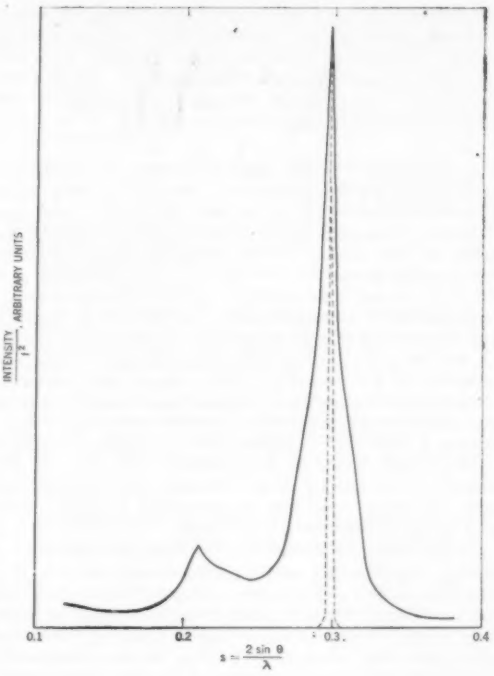


Fig. 1

We wish to thank V. Tiensuu for assistance in the interpretation of the X-ray patterns.

Raphael Raymond
Leslie Reggel
Waldo A. Steiner
Sabri Ergun
Irving Wender

Central Experiment Station,
Bureau of Mines, Region V,
Pittsburgh. Oct. 26.

[1] Fisher, C. H., Sprunk, G. C., Eisner, A., O'Donnell, H. J., Clarke, L., and Storch, H. H., Bureau of Mines Technical Paper 642, 44 (1942), and references cited therein.

[2] Reggel, L., Raymond, R., Friedman, S., Friedel, R. A., and Wender, I., *Fuel*, **37**, 126 (1958). Reggel, L., Raymond, R., and Wender, I., Abstracts of Papers, Division of Gas and Fuel Chemistry, 135th Meeting, American Chemical Society, Boston, Mass. (April 1959).

[3] Reggel, L., Friedel, R. A., and Wender, I., *J. Org. Chem.*, **22**, 891 (1957). Reggel, L., Friedman, S., and Wender, I., *ibid*, **23**, 1136 (1958).

BIOCHEMISTRY

Violinoid Products of Oxidation of *d*-Urobilin

Some confusion has recently arisen over the nature of the pigments derived from d-urobilin (I) by treatment with methanolic ferric chloride in the presence of hydrochloric acid. Watson[1] claims that this urobilin, after treatment for 15 min. under conditions similar to those described below, affords mainly glaucobilin (II). This finding differs from our own[2], which suggested that mesobiliviolins were the main products. Watson obtained mesobiliviolin only after brief treatment of d-urobilin with ferric chloride.

We have now confirmed that our original conditions of oxidation[2] convert d-urobilin mainly to violinoid pigments (λmax. 560–600 mμ in 2·8 N hydrochloric acid, 570 mμ in chloroform and 630,580 mμ for the zinc complex in methanol; these bands being

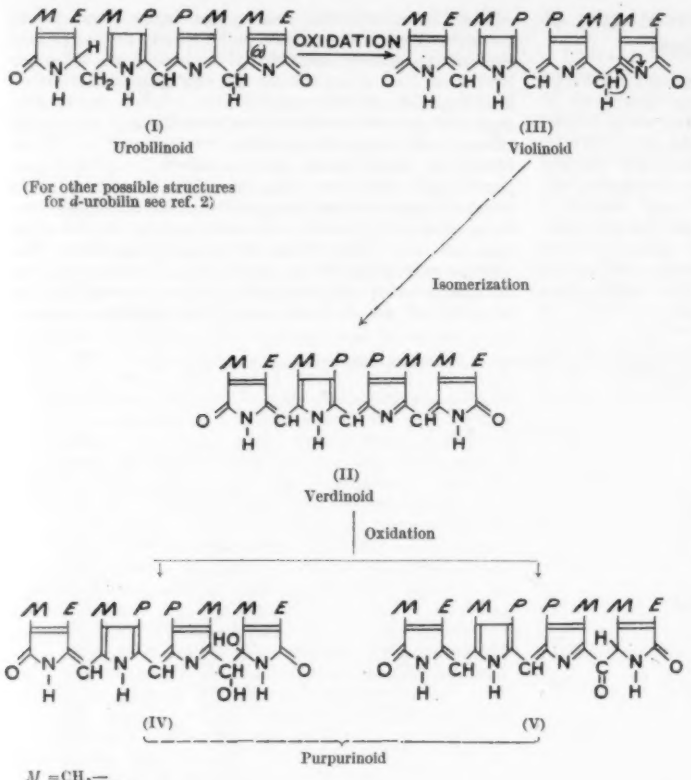


Fig. 1

diminished with formation of a third band at 510 mμ on addition of iodine). We have also found that further treatment with ferric chloride converts these violins to glaucobilin, so that they must be true violins, that is, bilidienes (III)[3]; and not the spectroscopically similar bilipurpurins[4], that is, compounds like (IV) and (V) derived from verdins (II) by oxidative saturation of one methene group. Further study of the problem has shown that even minor changes in our procedure can, according to conditions, give glaucobilin, mesobiliviolin, mesobilipurpurin or a mixture of these pigments. The nature of the products depends, among other things, upon the time of ferric chloride oxidation, dilution of the reaction mixture and extraction of products.

200-μgm. quantities of *d*-urobilin hydrochloride, with $(\alpha)_D$ (in chloroform) +5,000, were obtained by evaporation of appropriate volumes of chloroform solution. After solution in 2 ml. methanol the pigment was boiled, under reflux, with 1 ml. of 25 per cent (w/v) solution of ferric chloride in 11 *N* hydrochloric acid. After addition of 4 ml. of saturated aqueous sodium acetate solution and sometimes dilution, the oxidation products were extracted into ether. The pigments were taken from ether into 2·8 *N* hydrochloric acid; absorption spectra of the acid solutions were measured and the pigments were extracted into chloroform. After washing and filtration the spectra were again determined.

When the solutions were boiled for 10–15 min. and the pigments extracted without dilution, glaucobilin accompanied by small quantities of violin was formed, as was apparent from the absorption spectra. On refluxing for 15–18 min. the reaction mixture, still initially green, on dilution rapidly (1–5 min.) acquired a pink-violet colour due to the formation of violinoid pigments (λmax.: 540–560 mμ in chloroform, 580–590 mμ in 2·8 *N* hydrochloric acid and 620, 575–585 mμ for the zinc complex in methanol; on addition of iodine to the last solution there was depression of the existing two peaks, and an additional peak appeared at 510 mμ). These pigments would not undergo further oxidation to verdin on treatment with ferric chloride and were therefore assumed to be purpurins rather than true violins; the behaviour of their chloroform solution on treatment with 1 per cent hydrochloric acid suggests that they are in fact mesobilipurpurins-II (for example, V)[4]. Refluxing for 30 min. gave a reaction mixture from which glaucobilin alone could be isolated independently of dilution or interval between end of reaction and extraction of product.

It is evident that glaucobilin formation by oxidation with ferric chloride is more rapid than the corresponding reaction with *i*-urobilin. We suggest that a possible reason for this is that violin, initially formed by dehydrogenation of one bridge carbon atom and its adjacent α-pyrrole carbon atom, undergoes rapid isomerization to verdin by the prototropic change formulated in Fig. 1. A similar change is impossible for *i*-urobilin since it lacks the necessary unsaturation (*a*) present in *d*-urobilin[2].

In agreement with this mechanism is the fact that *d*-urobilin can be isomerized to a true violin, unaccompanied by glaucobilin, by anaerobic treatment with alkoxides; these are effective catalysts for changes such as those shown in Fig. 1[5,2]. The mechanism is, however, not in accord with a recent observation of Watson (private communication) that in ferric chloride oxidation *d*-urobilin IXα behaves more like *d*-urobilin than *i*-urobilin. If this observation is confirmed, the structures postulated for *d*-urobilin and *d*-urobilin–IXα[2] may need revision, for the latter has hitherto been considered optically isomeric with *i*-urobilin.

C. H. Gray
D. C. Nicholson

Department of Chemical Pathology,
King's College Hospital Medical School,
London, S.E.5.
Sept. 24.

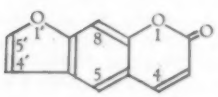
[1] Watson, C. J., and Weimer, M., *Fed. Proc.*, **18**, No. 1377 (1959); and Watson, C. J., private communication.
[2] Gray, C. H., and Nicholson, D. C., *J. Chem. Soc.*, **627**, 3085 (1958).
[3] Siedel, W., *Z. physiol. Chem.*, **237**, 8 (1935).
[4] Lemberg, R., and Legge, J. W., "Hæmatin Compounds and the Bile Pigments", 130–133 (Intersci. Pub., New York, 1949).
[5] Baker, J. W., "Tautomerism", 51 (Routledge, London, 1939).

Activating and Fluorescent Wave-lengths of Furocoumarins : Psoralens

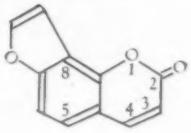
Biological photosensitized reactions are known to result from the absorption of a wide spectrum of radiation. The energy and therefore the wave-length of light absorbed and the biological changes occurring in photosensitized reactions are obviously closely related. A fundamental law of photochemistry, the Grotthus–Draper law, states that only radiation absorbed by the reacting system is effective in producing chemical change. Thus the radiation producing the photosensitizing reaction (that is, the action spectrum) should correspond to the absorption spectrum of the photosensitizing agent.

The furocoumarins, more generally known as psoralens, have been shown to be highly active photosensitizing agents capable of inducing sunburn or erythema and augmenting the skin pigmentation[1–3]. Furthermore, these compounds inhibit enzymatic activities as well as exhibit bactericidal and fungicidal effects following ultra-violet irradiation[4–7]. Their effect on ultra-violet carcinogenesis in albino and pigmented mice has also been investigated[8,9]. In most of these studies long-wave ultra-violet light has been observed by several investigators to be more effective in evoking these biological responses. The precise activating wave-length range was not known. In the course of examining the photosensitizing activity of 45 natural and synthetically prepared

Table 1. Activating and Fluorescent Wave-lengths of Furocoumarins and Related Compounds



Psoralen



*Iso*psoralen

No.	Compound	Activity erythemal response	Activating wave-lengths (mμ)	Fluorescence wave-lengths (mμ)
1.	Psoralen	Active	270, 360	435
2.	4-methyl psoralen	Active	265, 315, 360	420
3.	5′, 8-dimethyl psoralen	Active	270, 375	440
4.	4, 4′-dimethyl psoralen	Active	270, 360	435
5.	4, 5′, 8-trimethyl psoralen	Active	270, 370	440
6.	3, 4, 5′, 8-tetramethyl psoralen	Active	270, 360	430
7.	5′, 4, 8-trimethyl-3*a*-butyl psoralen	Active	275, 375	430
8.	8-methoxy psoralen (xanthotoxin)	Active	280 360	360 460
9.	5-methoxy psoralen (bergapten)	Active	270 280 350	370 485 460
10.	5′, 4-dimethyl-8-acetyl psoralen	Active	320, 370	430
11.	5′, 4-dimethyl-8-*n* propyl psoralen	Active	270, 360 400 450	430 460 525
12.	5′, 4-dimethyl-8-acetamido psoralen	Active	275, 360, 390	450
13.	5′, 4-dimethyl-8-acetyl-semicarbazone	Active	360	440
14.	5′, 8-dimethyl-3, 4-benzo psoralen	Active	270, 300, 355	455
15.	5′, 8-dimethyl-3, 4-tetrahydrobenzo psoralen	Active	270, 360	430
16.	8-bromo-5′, 4-dimethyl psoralen	Active	275 375	430 460
17.	Marmesin (5′ isopropenol [2″]-4′, 5′-dihydro psoralen)	Active	270, 360	430
18.	Anhydro marmesin (5′ isopropyl-psoralen)	Active	270, 365	450
19.	5′ isopropenol [2″]-2 carboxy-4′, 5′-dihydro psoralen	Active	290, 340	380
20.	5′-methyl-isopsoralen	Active	280, 350, 400	460
21.	4′, 5′-dihydro-3-bromo-8-methoxy psoralen	Active	295, 380, 550	450
22.	5′, 4-dimethyl-8-amino psoralen	Inactive	380	530
23.	4′, 5′-dihydro-4-methyl psoralen	Inactive	280, 360, 545	395
24.	4′, 5′-dihydro-8-methoxy-psoralen	Inactive	280, 365 450	480 525
25.	4′, 5′-dihydro-3, 5-dibromo-8-methoxy-psoralen	Inactive	280 290 300, 375	320 400 470
26.	5-bromo-8-methoxy psoralen	Inactive	280, 365 450	480 525
27.	5, 8-dimethoxy psoralen	Inactive	290, 360, 450	530
28.	4′, 5′-dihydro-5-ethylcarbamyl-8-methoxy psoralen	Inactive	290, 360 280	495 380
29.	8-hydroxypsoralen	Inactive	350	410
30.	4′, 5′-dihydro, 5′, 4-dimethyl-isopsoralen	Inactive	280, 355, 535	395
31.	2, 9-dimethyl-7H-furo-[3, 2-*f*-] [1]-benzopyran-7-one	Inactive	270, 360	435
32.	2, 9-dimethyl-7-H-oxazolo-[4, 5-*f*]-[1]-benzopyran-7-one	Inactive	265, 335 400 450	400 450 525
33.	benzoxazole-5-acrylic acid-6-hydroxy-β-7-dimethyl-γ-lactone	Inactive	350, 400	410, 470
34.	benzoxazole-5-acrylic acid-2, 6-dihydroxy-β-7-dimethyl-γ-lactone	Inactive	270 265, 380 310	470 490 420
35.	benzoxazole-5-acrylic acid-6-hydroxy-β-2-7-trimethyl-γ-lactone	Inactive	270, 310, 355 400	400 470
36.	benzoxazole-5-acrylic acid-6-hydroxy 2-isopropyl-β-7-dimethyl-γ-lactone	Inactive	270, 310, 355	400
37.	2-carboxy-5, 6-dihydro-8-methoxy-benzo-(1, 2-b, 5, 4-b′)-difuran	Inactive	265, 335	430

Table 2. Activating and Fluorescent Wave-Lengths of Furocoumarins

Compounds	Total	Activating λ (265–280 mμ)	Fluorescent λ (420–460 mμ)	Activating λ (340–380 mμ)	Fluorescent λ (420–460 mμ)
Biologically active*	21	15		20	
Biologically inactive*	16	2		2	

* As measured by erythemal response.

psoralens, it has been observed[10,11] that linearly annulated condensed tricyclic structure of psoralen exhibited optimum photosensitization on human as well as guinea pig skin.

Since fluorescence behaviour represents the emission from the activated molecules of absorbed light energy, we investigated the activating and the fluorescent wave-lengths of 37 furocoumarins and their biological photosensitizing action (Table 1). An Aminco–Bowman spectrophotofluorimeter was used in this study[12]. Each compound was dissolved in 95 per cent ethanol (1 mgm./10 ml.) and an aliquot used for determining the activation and fluorescent wave-lengths. The method for determining the biological photosensitization of furocoumarins and their relative activity as measured by erythemal response has been detailed elsewhere[10,11].

As indicated in Tables 1 and 2, the region of activating wave-lengths for photosensitizing action of furocoumarins lies between 265 and 280 mμ in the short ultra-violet range and between 340 and 380 mμ in the long-wave ultra-violet range. The fluorescence peaks for these activating wave-lengths were observed in the region of 420–460 mμ. The percentage fluorescence emitted was always significantly high when the activating wave-lengths were 340–380 mμ. Furocoumarins which induced definite photosensitized erythemal response on mammalian skin (human as well as guinea pig) showed this region of exciting wave-lengths. The inactive furocoumarins which did not exhibit photosensitizing response in general did not show these specific activating and fluorescent peaks. It appears that furocoumarins which show activation peaks in the region of 340–380 mμ and concomitantly the fluorescent peaks in the region of 420–460 mμ can cause photosensitization of skin in this region of long-wave ultra-violet light. The action spectra for these photosensitizing compounds therefore appears to be in the region of 340–380 mμ.

The interest of Dr. Farrington Daniels, jun., and Dr. Thomas B. Fitzpatrick in this work is gratefully acknowledged. We also wish to thank Dr. K. D. Kaufman, Kalamazoo College, Kalamazoo, Michigan, the Paul B. Elder Company, Bryan, Ohio, the Upjohn Company, Kalamazoo, Michigan, and Dr. A. Chatterjee, University College of Science and Technology, Calcutta, India, for providing compounds for this study.

This investigation was supported by United States Public Health Service grant number *C*-2837 (*C*3) and *B*-1572 (*C*151).

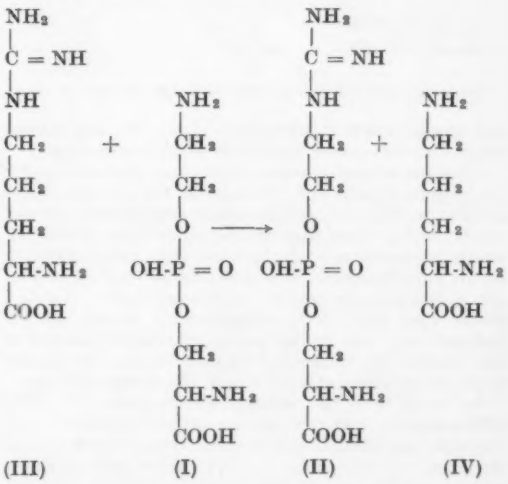
M. A. Pathak
J. H. Fellman

Departments of Dermatology and Biochemistry,
University of Oregon Medical School,
Portland 1, Oregon. Oct. 6.

[1] Fitzpatrick, T. B., Hopkins, C. E., Blickenstaff, D. D., and Swift, S., *J. Invest. Dermat.*, **25**, 187 (1955).
[2] Psoralens and Radiant Energy; Proceedings of a Symposium, *J. Invest. Dermat.*, **32**, 132 (1959).
[3] Musajo, L., Rodighiero, G., and Caporale, G., *Bull. Soc. Chim. Biol.*, **36**, 1213 (1954).
[4] Pathak, M. A., and Fowlks, W. L. (in the press).
[5] Pathak, M. A., and Fellman, J. H. (to be published).
[6] Fowlks, W. L., Griffith, D. G., and Oginsky, E. L., *Nature*, **181**, 571 (1958).
[7] Chakraborty, D. P., Das Gupta, A., and Bose, P. K., *Ann. Biochem. and Exp. Med.*, **17**, 57 (1957).
[8] O'Neal, M. A., and Griffin, A. C., *Cancer Res.*, **17**, 911 (1957).
[9] Pathak, M. A., Daniels, F., jun., Hopkins, C. E., and Fitzpatrick, T. B., *Nature*, **183**, 728 (1959).
[10] Pathak, M. A., and Fitzpatrick, T. B., *J. Invest. Derm.*, **32**, 509 (1959).
[11] Pathak, M. A., Fellman, J. H., and Kaufman, K. D. (in the press).
[12] Bowman, R. L., Caulfield, P. A., and Udenfriend, S., *Science*, **122**, 32 (1955); **122**, 972 (1955).

Biosynthesis of Lombricine

It was previously suggested[1,2] that serine ethanolamine phosphodiester (I) was the biological precursor of lombricine (II), a substance first isolated from earthworms by Thoai and Robin[3]. This suggestion was strengthened by the discovery of serine ethanolamine phosphodiester in earthworms[2,4] and by the finding that the serine moiety of both lombricine[5] and serine ethanolamine phosphodiester[4] had the unusual D-configuration. Experiments with inorganic phosphorus-32, [1 : 2-^{14}C] ethanolamine and DL-[3-^{14}C] serine have now provided additional evidence for this view. Furthermore, experiments with L-[amidino-^{14}C] arginine have shown that the amidino group of lombricine is derived from the amidino group of arginine (III), probably by a transamidinase catalysed transfer of the amidino group to serine ethanolamine phosphodiester with the formation of ornithine (IV):



The labelled precursors were administered to earthworms (*Megascolides cameroni*) in the amounts and specific radioactivities shown in Table 1. The labelled substances were given from a micro-syringe through a fine polythene tube inserted into the gastrointestinal tract of the worm for a distance of at least 3 cm. After the stated interval of time the worm was killed for the determination of the specific radioactivities of serine ethanolamine phosphodiester and lombricine (Table 1). The muscle was dissected out and extracted with 1·5 *N* perchloric acid. The extract was neutralized and then desalted on a 'Zeokarb 225' ion-exchange column (H^+ form). After concentration, the serine ethanolamine phosphodiester and lombricine were separated chromatographically on sheets of Whatman No. 3 filter paper with the solvents ethanol/formic acid/water (17 : 10 : 20 by vol.) and phenol/water (4 : 1 w/v). The specific radioactivities of the eluted serine ethanolamine phosphodiester and lombricine were determined using standard techniques. In some experiments the eluted lombricine was hydrolysed for 24 hr. at 110° in the presence of 6 *N* hydrochloric acid in a sealed tube, for determination of the distribution of radioactivity in the lombricine molecule (Table 2). The products of hydrolysis were separated chromatographically on paper strips with the phenol/water solvent. Serine from the serine moiety of lombricine and a combined area, representing guanidinoethanol

Table 1. *In vivo* Incorporation of Radioactivity from Labelled Precursors into Serine Ethanolamine Phosphodiester and Lombricine of Earthworm Muscle

Precursor	Amount administered (μmoles/gm.)	Radioactivity administered (c.p.m./gm.)	Time intervals (days)	Specific radioactivity (c.p.m./μmole)	
				Serine ethanolamine phosphodiester	Lombricine
Inorganic ^{32}P	carrier-free	$1{\cdot}1 \times 10^6$	2	560	20
Inorganic ^{32}P	carrier-free	$1{\cdot}1 \times 10^6$	4	840	97
[1 : 2-^{14}C] ethanolamine ..	3·7	$7{\cdot}5 \times 10^6$	4	67,900	1080
DL-[3-^{14}C] serine	2	10^7	2	31,500	904
L-[*amidino*-^{14}C] arginine ..	40	10^6	2	negligible*	329

* Net counting rate less than one-half the background counting rate.

Table 2. Distribution of Radioactivity in Labelled Lombricine of Earthworm Muscle

Precursor	Counts in serine moiety (per cent of total)	Counts in guanidinoethanol moiety (per cent of total)
[1 : 2-^{14}C] ethanolamine	6	94
DL-[3-^{14}C] serine ..	76	24
L-[*amidino*-^{14}C] arginine	negligible*	97

* Net counting rate less than one-half the background counting rate.

and guanidinoethyl phosphate from the guanidinoethanol moiety, were eluted for further counting.

After the administration of inorganic phosphorus-32, [^{14}C] ethanolamine and [^{14}C] serine, the specific radioactivity of the serine ethanolamine phosphodiester was much greater than that of the lombricine (Table 1), which is consistent with the view that serine ethanolamine phosphodiester is a precursor of lombricine and not a degradation product of that molecule. Table 2 shows that with [^{14}C] ethanolamine almost all the radioactivity was in the guanidinoethanol portion of the lombricine molecule, whereas with [^{14}C] serine most of the radioactivity was in the serine portion.

In contrast to the findings for inorganic ^{32}P, [^{14}C] ethanolamine and [^{14}C] serine, when L-[amidino-^{14}C] arginine was administered to the earthworm there was negligible radioactivity in the serine ethanolamine phosphodiester and considerable activity in the lombricine (Table 1). Almost all the radioactivity was in the guanidinoethanol moiety of the lombricine, indicating that at least one carbon atom of that portion of the molecule was derived from the carbon atom of the amidino group of arginine.

These findings strongly suggest that in the earthworm under *in vivo* conditions serine ethanolamine phosphodiester is the precursor of lombricine and that the amidino group of lombricine is derived from arginine by a transamidinase catalysed reaction.

R. J. Rossiter*
T. Gaffney†
H. Rosenberg
A. H. Ennor

Department of Biochemistry,
John Curtin School of
Medical Research,
Australian National University,
Canberra.

* On study leave from Department of Biochemistry, University of Western Ontario, London, Canada.
† Australian National University Scholar.

[1] Ennor, A. H., and Morrison, J. F., *Physiol. Rev.*, **38**, 631 (1958).
[2] Rosenberg, H., and Ennor, A. H., *Biochem. J.* (in the press).
[3] Thoai, N. v., and Robin, Y., *Biochim. Biophys. Acta*, **14**, 76 (1954).
[4] Ennor, A. H., Rosenberg, H., Rossiter, R. J., Beatty, I. M., and Gaffney, T., *Biochem. J.* (in the press).
[5] Beatty, I. M., Magrath, D. I., and Ennor, A. H., *Nature*, **183**, 591 (1959).

Dependence of Periodic Activation and Inhibition of Monoaminoxidase by Aliphatic Compounds upon Chain-length

Monoaminoxidase has been linked with vascular and mental activity[1-3]. Among the most ancient modifiers of mental status are the alcohols, which have been shown[4] to modify monoaminoxidase *in vitro*. During our endeavours to develop this correlation further, we encountered a puzzling periodic activation and inhibition of this enzyme. For five years, the postulation of a tenable explanation has escaped not only our own interpretative capacities, but also those of the recognized specialists whom we have consulted. The recent studies of aliphatic compounds which have accompanied the discovery of irin[5] have provided our experiments with added interest: it now seems possible that enzymatic modification by aliphatic compounds might constitute a regulatory mechanism in the contraction of smooth muscle.

The determinations of monoaminoxidase activity were performed on rat liver homogenates and on isolated mitochondria with analytical methods previously discussed[6]. Among them the most reliable one[7] is the simple measurement of ammonia evolution[8]. Therefore only the results obtained with that method are shown here, although respirometry yielded qualitatively similar results whenever concomitantly performed.

The modification of the aminoxidase activity in a liver homogenate as a function of the chain-length of normal aliphatic alcohols is shown in Fig. 1. The alcohols had been subjected to elemental analysis which showed the absence of significant contaminants. The molarity of the alcoholic additives was $1{\cdot}5 \times 10^{-6} M$ for all the samples; the controls had saline added. The substrates were the hydrochlorides of tyramine and 1-norepinephrine (50 μmoles per ml. of reaction mixture). Short pre-incubations of the samples with the alcohols alone did not materially affect the results. The incubations were carried out at 4°C. since the modification was less pronounced at 37°C. and was diminished even more by higher temperatures. The results are expressed as percentages of the average reaction velocity of the control. The tyramine experiment is represented on the left ordinate and the norepinephrine results on the right. It is evident that the maxima and minima differ between the two substrates.

We have shown earlier that monoaminoxidase is intimately attached to the mitochondria of the rat liver cells[9] and that it may be rendered water-soluble by the use of suitable detergents[10]. At present, the most convenient detergent seems to be 'Igepal CO-630'[11]. As reported previously[10], the solubilization of this enzyme is accompanied by a significant increase in measurable activity. Thus it was of

interest to determine whether the periodic phenomenon here discussed depended on the existence of intact mitochondria or whether the water-soluble enzyme-detergent complex also was capable of activation-inhibition with alcohols. Results with solubilized enzyme are summarized in Fig. 2 in the fashion discussed above. The normal alcohol concentration was $1{\cdot}8 \times 10^{-5}$ *M*. It is noteworthy that the activation phase was evident only with norepinephrine and that with this substrate the maxima and minima were shifted as a result of the enzyme's solubilization.

Long ago, Blaschko[12] published a summary of his experience with the oxidation of aliphatic diamines of various chain-lengths by monoaminoxidase preparations. We interpret this activity curve as being periodic. Furthermore, what we consider as being the maxima in Blaschko's curve correspond to the minima in our tyramine curve, while his minima correspond to our maxima. Thus the two are essentially enantiograms of each other. It seems, therefore, that the phenomenon which we have encountered with alcohol additives might also be occurring when a homologous series of substrates are tested without any additive. It is also pertinent that the enzyme under discussion is sensitive to the substrate concentration, since we have described earlier[8] a marked temperature-dependent inhibition caused by high substrate concentrations. It was of interest therefore to study permutations of homologous series of substrates and of alcohols in order to discover the nature of the complementarity displayed by this system. As yet we have been unable to secure a homologous series of substrates in sufficiently pure form for enzymatic work.

In an effort to discover other aliphatic modifiers, we have investigated several series of aliphatic compounds. Of these the normal hydrocarbons have shown a behaviour qualitatively similar to the alcohols: a progressively increasing inhibition of the aminoxidase reaction was seen when the gaseous hydrocarbons were added to the atmospheric oxygen in equimolar concentrations. With the liquid hydrocarbons the modification of the enzyme occurred only in some of the experiments. When it did occur, it was as pronounced as with the alcohols. We have not as yet discovered the variable which caused this all-or-none response of our preparations. The normal saturated fatty acids and their methyl esters were inactive in several experiments.

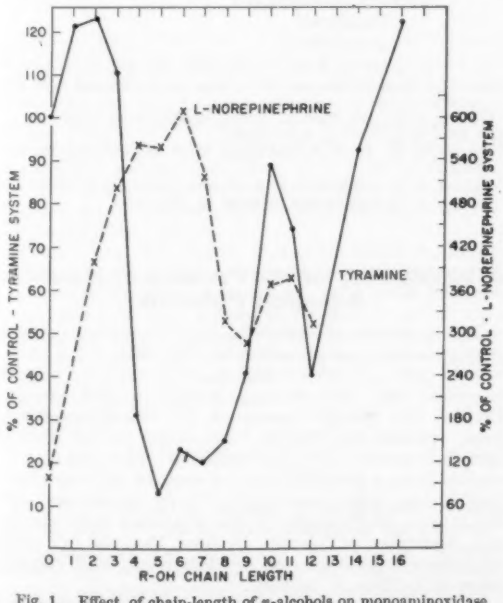


Fig. 1. Effect of chain-length of *n*-alcohols on monoaminoxidase activity of rat liver homogenate, as measured with the substrates indicated

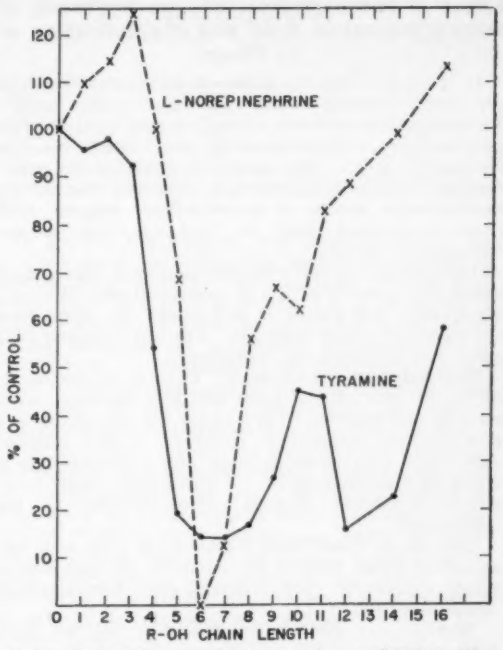


Fig. 2. Same as Fig. 1 but the homogenate was solubilized with detergent

It is evident that mammalian aminoxidase is amenable to periodic activation and inhibition by homologous series of some aliphatic compounds *in vitro*. The mechanism of this interesting phenomenon as well as its possible *in vivo* counterparts will require further work for their final definition.

This work was supported by the U.S. Atomic Energy Commission.

GEORGE C. COTZIAS
JAMES J. GREENOUGH

Medical Research Center,
Brookhaven National Laboratory,
Upton, Long Island, New York.
Sept. 29.

[1] Bogdanski, D. F., and Udenfriend, S., *J. Pharmacol. and Exp. Therap.*, **116**, 7 (1956).
[2] Broadie, B. B., Pletscher, A., and Shore, P. A., *J. Pharmacol. and Exp. Therap.*, **116**, 9 (1956).
[3] Broadie, B. B., Tourich, E. G., Kuntzman, R., and Shore, P. A., *J. Pharmacol. and Exp. Therap.*, **119**, 461 (1957).
[4] Heim, F., *Arch. Exp. Path. Pharmakol.*, **210**, 16 (1950).
[5] Ambach, N., *J. Physiol.*, **146**, 255 (1959).
[6] Cotzias, G. C., and Greenough, J. J., *Arch. Biochem. Biophys.*, **75**, 15 (1958).
[7] Cotzias, G. C., and Greenough, J. J., *Nature*, **183**, 1732 (1959).
[8] Cotzias, G. C., and Dole, V. P., *J. Biol. Chem.*, **190**, 665 (1951).
[9] Cotzias, G. C., and Dole, V. P., *Proc. Soc. Exp. Biol. and Med.*, **78**, 157 (1951).
[10] Cotzias, G. C., Serlin, I., and Greenough, J. J., *Science*, **120**, 114 (1954).
[11] Product of Antara Chemicals, a division of General Aniline and Film Corp.
[12] Blaschko, H., *Pharmacol. Rev.*, **4**, 415 (1952).

Effect of Nitroacridine 3663 on Synthesis of Deoxyribonucleic Acid and Multiplication of T_2 Phage

It is known that the different acridine derivatives are able to become bound to isolated nucleic acids[1]. The compounds are more strongly bound by the highly polymerized deoxyribonucleic acid than by the ribonucleic acid[1]. The results of studying the interactions with deoxyribonucleic acid and the strong antibacterial effects of nitroacridine[2] suggest that these compounds may be used as virus chemotherapeutic agents.

The purpose of this work was to obtain information about the mode of action of nitroacridines. We used *Escherichia coli* strain *B* and phage T_2, employing the standard phage methods. The nitroacridine 3663 used was described by Schnitzer[2].

Bacteria were grown at 37° C. to a concentration of 2×10^8 per ml. in 2,500 ml. *M*-9 medium, sedimented and infected with 5 phage per bacterium in a non-nutrient adsorption medium[3]. The infected cells were then re-sedimented and transferred to a warm *M*-9 medium at 2×10^8 cells per ml. (zero time) which contained various concentrations of the compound.

The phage yields were measured at time zero and at other times from 1-ml. samples, diluted into a lysing medium[4] for intracellular bacteriophage determinations.

Immediately after infection and at various times later, samples of 500 ml. were withdrawn from the culture flask and quickly poured into 50 ml. of 3 *M* trichloroacetic acid. The fractions of deoxyribonucleic acid of the 500-ml. samples were obtained by a modified Schmidt–Thannhauser procedure[5]. Small aliquots of the trichloroacetic acid extracts containing deoxyribonucleic acid were analysed for deoxyribose by the diphenylamine method. The bulk of the extracts of deoxyribonucleic acid were evaporated to dryness and then hydrolysed[6]. The hydrolysates were chromatographed[6] and the amounts of the 5-hydroxymethylcytosine were determined spectrophotometrically.

The growth of the *E. coli B* was measured in *M*-9 medium by the colony plate count and by the nephelometric method. The compound was added in various concentrations to the culture when the growth was in the logarithmic phase.

As shown in Fig. 1, nitroacridine 3663 inhibits the synthesis of infective T_2 phage similarly to proflavine[4]; at the same time it has no effect on the multiplication of the host cell. The inhibition of the phage deoxyribonucleic acid occurs only at higher acridine concentrations. The degree of inhibition agrees entirely with the host cell.

It is thus seen that the effect of nitroacridine 3663 depends on the concentration of the compound. At very low concentrations (0·05–0·15 μgm./ml.) it inhibits the synthesis of T_2 phage without inhibiting the multiplication of the host cell. To account for this phenomenon it appears that during the vegetative phase of phage development the protein and deoxyribonucleic acid parts of phage are synthesized separately by the host cell[7]. The compound is bound more strongly by the structure-free phage deoxyribonucleic acid than by the structural nucleoproteins of the host. The deoxyribonucleic acid-acridine compound formed cannot be organized into an infective phage. In other words, this compound is a decoupling agent of the synthesis of phage nucleoprotein.

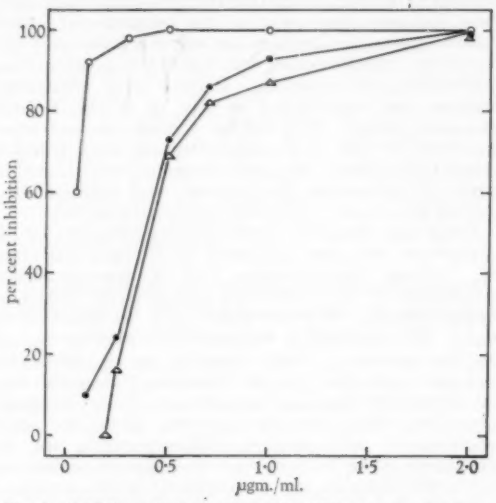


Fig. 1. Inhibitory effect of nitroacridine 3663 on —●—●—●— phage deoxyribonucleic acid synthesis (●); —○—○—○— multiplication of T_2 phage (○) and —△—△—△— multiplication of *E. coli B* (△), in per cent of untreated controls

At higher concentrations the compound inhibits the synthesis of phage deoxyribonucleic acid as well as the multiplication of *E. coli B*. The inhibitory effect is similar. From this observation it is concluded that the bacteriostatic effect of the compound is displayed by the inhibition of the synthesis of deoxyribonucleic acid.

Details of the relations of the structure and the effect of the different nitroacridines will be published elsewhere.

G. Dénes
L. Polgár

Institute of Medical Chemistry,
University of Budapest,
Budapest.
Aug. 13.

[1] Irvin, J. L., and Irvin, E. M., *J. Biol. Chem.*, **206**, 39 (1954).
[2] Schnitzer, R., and Silberstein, W., *Z. Hyg. Infektionskrankh.*, **109**, 519 (1929).
[3] Hershey, A. D., and Chase, M., *J. Gen. Physiol.*, **36**, 39 (1952).
[4] De Mars, R. I., *Virology*, **1**, 83 (1955).
[5] Hershey, A. D., Dixon, J., and Chase, M., *J. Gen. Physiol.*, **36**, 777 (1953).
[6] Vidaver, G. A., and Kozloff, L. M., *J. Biol. Chem.*, **225**, 335 (1957).
[7] Hershey, A. D., The Harvey Lectures, **51**, 229 (1957).

A Simple Test for the Presence of Metals in Biological Materials

The presence of metals in highly purified protein preparations is of considerable interest. The paramount part played by metals, especially in enzyme reactions (see, for example, ref. 1), is well known. Besides the specific metals in the metalloproteins, most proteins are able to bind, more or less firmly, metals removed from the medium. The removal of metals from a protein solution may be an important preliminary step in a study of its properties and structure. Unfortunately, the available methods for the detection of metals involve the use of very expensive equipment, or are laborious, and require large quantities of protein.

A very simple, non-specific test was devised to demonstrate the presence of metals in protein

preparations. It is based on the spectral changes which occur when 8-hydroxyquinoline chelates metals. Spectral changes in the range of 300–370 mμ have already been studied[2]; but changes also occur at lower wave-lengths and have been used for this test. The alkali and alkaline earth metals give no response or a very weak one.

At neutral *p*H, 8-hydroxyquinoline has a very sharp absorption peak at 239 mμ which is shifted when chelation occurs to between 250 and 255 mμ, according to the metal involved (Fig. 1). The absorption here is approximately ten times that reported in the region of 360 mμ. It is fortunate for the effectiveness of the test that in this region of the spectrum most proteins have a minimal absorption.

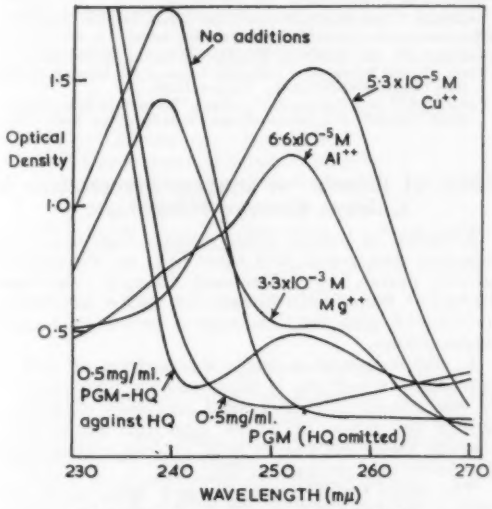


Fig. 1. Spectra of 8-hydroxyquinoline chelates. *Tris* *p*H 7·5, 3·3 millimolar; 8-hydroxyquinoline, $5·0 \times 10^{-5}$ molar. Final volume 3·0 ml.

The general procedure for the test was as follows: The absorption of the protein (1 mgm. or less) in 1·0 ml. of 3·0 m*M* *tris*-chloride buffer *p*H 7·5 (the ionic strength was found not to be critical, stronger buffer can be used if necessary) was measured in a 'Unicam *SP* 500' spectrophotometer at 280 and 253 mμ against the same solution with protein omitted. To both blank and sample, 0·02 ml. of 2·5 m*M* 8-hydroxyquinoline was added and a reading at 253 mμ was made after mixing.

Precautions were taken to ensure that both blank and sample contained exactly the same constituents (except for the protein solution). The same pipettes were used and special care was taken to avoid contamination during mixing. Glass-distilled water was used, and was further de-ionized when very accurate determinations were required.

Results were expressed as:

$$\Delta E_{253/\text{mgm.}} = \frac{E' - E}{[\text{prot.}]}$$

where E is the optical density of the protein solution at 253 mμ, E' the optical density of the protein–8-hydroxyquinoline mixture minus the optical density of 8-hydroxyquinoline at 253 mμ, and [prot.] represents the protein concentration in mgm./ml. calculated from the E_{280} value.

Table 1. Ultra-Violet Absorption Characteristics of Some Metal Chelates of HQ

Metals	Position of the peak mμ	Calculated absorption in presence of m*M* metal ions at 253 mμ
Ca^{++} and Ba^{++}	No peak observed.	—
Mg^{++}	255	0·125
Mn^{++}	253	1·170
Zn^{++}	255	25·000
Cu^{++}	254	57·200
Al^{+++}	251	17·200

HQ test as indicated in the text, but without protein. Sulphates of zinc, copper and aluminium, and the chlorides of the other metals were used.

In general the reaction was instantaneous; but in some cases the maximum absorption value was reached more slowly. The position of the peak varies slightly according to the metal as shown in Table 1, which also gives the calculated values of the optical densities for millimolar concentrations of some metals. Insolubility of the complexes was not found to be a problem, due to the very dilute solutions used, but at higher concentrations the optical density decreased after standing for a few minutes.

The test was applied to a crystalline phosphoglucomutase preparation[3], using between 0·3 and 0·8 mgm. protein per test. Phosphoglucomutase dialysed for 24 hours against large volumes of glass-distilled water gave a $\Delta E_{253/\text{mgm.}}$ value of 0·560 (Fig. 1). (From Table 1 a $\Delta E_{253/\text{mgm.}}$ value of 0·040 would correspond, for example, to about 0·06 mole of Cu^{++}, 0·2 mole of Zn^{++} or 2 mole of Mn^{++} per mole of enzyme (mol. wt. 74,000).) Passing this enzyme preparation through a carboxylic resin reduced the $\Delta E_{253/\text{mgm.}}$ to a negligible value, whereas dialysis against ethylenediaminetetraacetic acid, followed by exhaustive dialysis against glass-distilled water, increased this value.

The test was also used to follow the purification of phosvitin, which is known to contain iron, magnesium and calcium[5]. In this case the original $\Delta E_{253/\text{mgm.}}$ of 0·210 decreased to a negligible value after dialysis against ethylenediaminetetraacetic acid followed by extensive dialysis against water[6].

The test may also be applied to other materials provided that their absorption, at the wave-length used, is not too high. It proved very useful in showing metal contamination of one sample of glucose-1-phosphate which gave anomalous results when metal activation of phosphoglucomutase was studied. After passing the substrate through a sulphonic resin this anomaly was removed.

The 253 mμ peak was also used instead of the 360 mμ one in the determination of dissociation constants according to Burton[7] and for quantitative estimation of copper in pure solutions[4].

This work was carried out during the tenure of a scholarship awarded by the British Council, while on leave from the Instituto Nacional de Microbiologia, Buenos Aires. I am grateful to Dr. Malcolm Dixon for his advice.

C. Milstein

Department of Biochemistry,
Tennis Court Road,
Cambridge.
Oct. 12.

[1] Vallee, B. L., "Adv. in Protein Chem.", 10, 318 (1955).
[2] Näsänen, R., *Acta Chem. Scand.*, 6, 352 (1952). Näsänen, R., and Penttinen, U., *Acta Chem. Scand.*, 6, 837 (1952).
[3] Najjar, V. A., *J. Biol. Chem.*, 175, 281 (1948).
[4] (Unpublished observations.)
[5] Mecham, D. K., and Olcott, H. S., *J. Amer. Chem. Soc.*, 71, 3670 (1949).
[6] Williams, J. (personal communication).
[7] Burton, K., *Biochem. J.*, 71, 388 (1959).

ANIMAL PHYSIOLOGY

Comparative Adenylic Acid Deaminase Activity in Choroid Plexus and Ciliary Process Tissue

Analogies between the ciliary process production of aqueous humour and the choroid plexus production of cerebrospinal fluid have been reviewed quite extensively by Davson[1]. The presence of an adenosine triphosphate-activated 5-adenylic acid deaminase in purified preparations of hog and rabbit ciliary process tissue[2,3] led to an interest in a similar system that might be present in choroid plexus tissue. It has, in fact, been shown by other investigators that 5-adenylic acid deaminase activity is present in preparations of whole dog brain[4,5].

Analytical methods employed in this investigation were as reported previously[2]. Incubations were done under the conditions described in Table 1.

Table 1. Deaminase Activity in Whole-Tissue Homogenates
μMoles recovered after 40 min. incubation

Enzyme source	ATP	ADP	AMP	IMP	Adenosine	Total	μMoles NH_3
Dog choroid plexus	4·44	2·20	1·64	0·70	6·03	15·01	0·76
Hog ciliary processes	4·10	4·03	2·94	2·78	—	13·85	3·83

All vessels contained: 0·03 *M tris*-0·03 *M* succinate buffer, *p*H 7·4; 3·8 per cent fresh whole tissue homogenate; 7 μmoles each adenosine triphosphate and adenylic acid; 0·004 *M* magnesium chloride; 0·005 *M* potassium chloride; 0·025 *M* sodium chloride.
ATP, adenosine triphosphate; ADP, adenosine diphosphate; AMP, adenylic acid; IMP, inosinic acid.

Although the results indicate that choroid plexus tissue does have an active deaminase system, it is clear from the nucleotide recovery data that there are differences in the metabolic exchanges in the two types of tissue studied. We cannot as yet preclude the possibility that ammonia accumulation in the choroid plexus system could have resulted from deamination of any of the adenine derivatives recovered. The stoichiometry between the ammonia produced and inosinic acid accumulated is, however, strongly suggestive of the ammonia yield being the result of 5-adenylic acid deamination.

The fact that ammonia production in the ciliary process preparation was 5 times greater than in the choroid plexus preparation makes one question the activating influence of adenosine triphosphate as a deaminase co-factor in the latter tissue. This co-factor role of adenosine triphosphate has been reported for purified ciliary process preparations[6].

It has been shown previously that the deaminase of ciliary process is specific for 5-adenylic acid[2]. A similar specificity is seen in preparations of choroid plexus incubated under the same conditions described in Table 1 except substituting 14 μmoles of 3-adenylic acid as the nucleotide addition in some vessels and 14 μmoles of 5-adenylic acid as the nucleotide addition in other vessels. A yield of 0·2 μmole of ammonia was seen in the former case and 1·2 μmoles of ammonia in the latter—a 6-fold increase in activity with 5-adenylic acid.

Precise functional evaluation of the roles of these deaminase systems as regards actual aqueous humour and cerebrospinal fluid production must await further investigation. A role of adenine nucleotides in regulation of blood vessel patency[7,8] and roles of adenylic acid in many areas of metabolic interactions[9], either of which could invoke the need of an adenylic acid concentration-regulating deaminase, have already been suggested by others.

This study was supported in part by Research Grant *B*-121 from the National Institute of Neurological Diseases and Blindness, National Institutes of Health.

Morton B. Waitzman
Laboratory for Research in Ophthalmology and
Department of Pharmacology,
Western Reserve University,
School of Medicine,
Cleveland 6, Ohio.
Oct. 26.

[1] Davson, H., "Physiology of the Ocular and Cerebrospinal Fluids" (Little, Brown and Co., Boston, 1956).
[2] Waitzman, M. B., and Ballintine, E. J., *Amer. J. Ophthal.*, **46**, No. 1, Part II, 96 (1958).
[3] Waitzman, M. B., *Fed. Proc.*, **18**, 165 (1959).
[4] Muntz, J. A., *J. Biol. Chem.*, **201**, 221 (1953).
[5] Mendicino, J., and Muntz, J. A., *J. Biol. Chem.*, **233**, 178 (1958).
[6] Waitzman, M. B., *Amer. J. Physiol.* (In the press).
[7] Kutscher, W., and Sarreither, W., *Klin. Wchschr.*, **26**, 698 (1948).
[8] Green, H., and Stoner, H., "Biological Action of the Adenine Nucleotides" (Lewis Publishing Co., London, 1950).
[9] Colowick, S. P., and Kaplan, N. O., editors, "Methods in Enzymology", **1**, 197, 365, 585, 713, 740 (Academic Press, Inc., New York, 1955).

Effect of Kinetin on Glucose Metabolism of Chicken Embryo Fibroblasts

Kinetin, a potent plant-growth hormone, was recently discovered and identified as 6-(furfurylamino) purine, by Miller and Skoog[1]. Orr and McSwain[2] found that kinetin, at rather low levels (0·015–0·06 μgm./ml.), stimulated growth of human tissue culture.

In the course of a study of the effect of various hormones on cultures of chick embryo fibroblasts[3,4], it was observed that graded amounts of kinetin within the range of 12–24 μgm./ml. produced a roughly linear increase of total glucose consumption and lactic acid production (Fig. 1).

The ratio between glucose and lactic acid was similar in hormone-treated and control cultures. A kinetin concentration which stimulated glucose metabolism caused only slight growth inhibition. Microscopic examination revealed no abnormalities in the morphological appearance of the cells grown in the presence of the hormone.

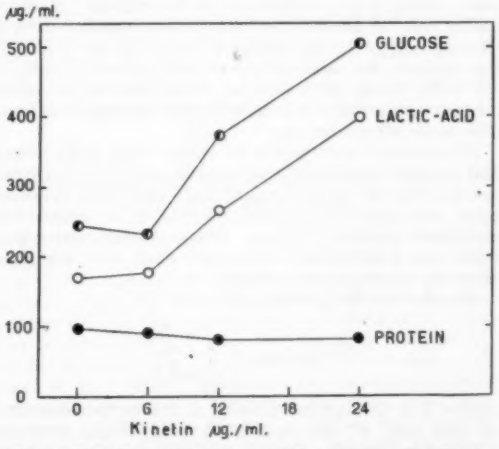


Fig. 1. The effect of kinetin on growth and glucose uptake of chick embryo fibroblasts and their lactic acid production. Procedures for cell cultivation and analytical methods were similar to those previously described (refs. 3 and 4). Cultures were incubated with hormone for 3 days prior to examination

In order to test the specificity of kinetin, a number of purines and pyrimidines and their derivatives were examined. Adenine and guanine showed a moderate and rather variable and irregular degree of stimulation; adenosine, guanosine, hypoxanthine, xanthine, cytosine, uracil and thymine did not affect glucose metabolism at a concentration up to 25 μgm./ml. Indoleacetic acid, another plant growth hormone known to affect the action of kinetin in plant tissues[5], did not modify the response of chick fibroblasts to kinetin, at a concentration up to 25 μgm./ml.

From the available data no conclusion can be drawn as to whether or not the described effect bears any relationship to the growth-promoting activity of kinetin in plants. The striking disparity between the effective levels in the two systems would rather indicate that the two phenomena are of an essentially different nature. It is not unlikely, however, that the quantitative difference is due to permeability factors.

S. Halevy
Lydia Avivi

Laboratory of Nutrition,
Department of Biochemistry,
Hebrew University–Hadassah Medical School,
Jerusalem. Aug. 11.

[1] Miller, C. O., and Skoog, F., *J. Amer. Chem. Soc.*, **78**, 1375 (1956).
[2] Orr, M. F., and McSwain, B., *Cancer*, **10**, 617 (1957).
[3] Halevy, S., and Avivi, L., *Biochim. Biophys. Acta*, **30**, 198 (1958).
[4] Halevy, S., and Avivi, L. (in the press).
[5] Skoog, F., and Miller, C. O., *Symp. Soc. for Exp. Biol.*, **11**, 118 (1957).

Urinary Hyaluronidase

Ginetzinsky recently described a relationship between urinary hyaluronidase and urine concentration[1]. He found that urinary hyaluronidase assayed by his method was high at low urine volumes, virtually disappearing during water diuresis; but it remained high during an osmotic diuresis. From these results he inferred that antidiuretic hormone might act by stimulating the production of hyaluronidase within the nephron; this would facilitate water re-absorption by allowing water to pass through the ground substance between the cells. In an attempt to confirm Ginetzinsky's findings it became clear that his method[2] is unsuitable for quantitative assay of urinary hyaluronidase for the following reasons:

(1) Precise estimation of hyaluronidase by any viscosimetric method is dependent on a constant electrolyte composition of the hyaluronidase–hyaluronic acid system, as was demonstrated in 1940 by Madinaveitia and Quibell[3], and by McLean and Hale[4]. Urine has a variable electrolytic composition, and as Ginetzinsky does not appear to make any correction for this, his results are not quantitative.

(2) Ginetzinsky[1] fails to express his results as hyaluronidase excreted per minute, relying solely on arbitrary units per ml. If hyaluronidase were excreted at a constant rate like creatinine, then a graph of its concentration against urine flow per minute would be similar to Ginetzinsky's Fig. 1.

(3) He measures the initial viscosity of the mixture of urine, buffer and hyaluronic acid, the measurement being repeated after twenty minutes incubation, and the per cent reduction in viscosity is expressed as arbitrary units. This procedure is open to error as there is a rapid fall in viscosity before the initial reading[3] if a high concentration of hyaluronidase is present.

The method has been modified to allow for these factors. A detailed account will appear elsewhere, together with the results; but in principle the following changes have been made in the method of McLean and Hale[4]:

(1) The electrical conductivity of the urine is determined and compared with sodium chloride standards, the conductivity being brought to a value equal to that of 0·1 *M* sodium chloride in the final system by addition of a mixture of molar sodium and potassium chlorides.

(2) A micro-Ostwald viscosimeter is calibrated with a standard hyaluronidase preparation, incubation being at 37°C. The hyaluronidase concentration of the urine is obtained by reference to the calibration curve, and converted to units excreted per minute.

The experimental conditions chosen were water diuresis and mannitol osmotic diuresis as employed by Ginetzinsky: in addition, observations were made during potassium diuresis.

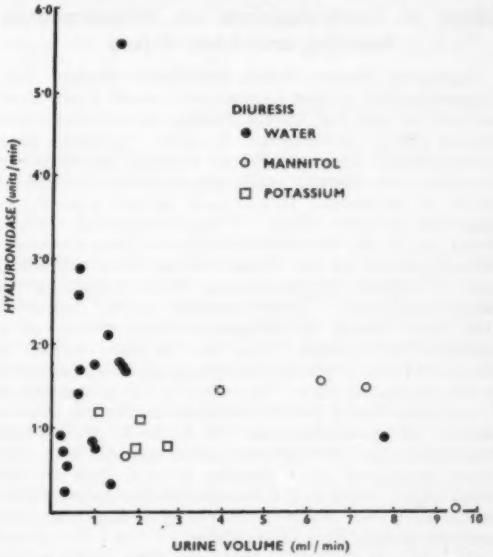


Fig. 1. Relationship of hyaluronidase output per minute to urine volume. There is no correlation between hyaluronidase excretion and urine minute volume in water diuresis or deprivation.

The results obtained demonstrate that first there is no relationship between hyaluronidase output (units per minute) and urine flow (ml. per min.) (Fig. 1). Secondly, there is in conditions of water deprivation and diuresis only an apparent relationship between hyaluronidase output and urinary osmolar excretion, sodium excretion and potassium excretion, the last three being interrelated. In osmotic diuresis in man with 25 per cent mannitol, hyaluronidase excretion remained at a fairly constant low level, in contrast to the findings of Ginetzinsky. If hyaluronidase concentration is plotted against urine minute volume (see Ginetzinsky's Fig. 2, ref. 2) there would naturally be a decrease in concentration as urine flow increases. Hyaluronidase excretion and potassium excretion both remain constant and are not related to sodium or osmolar excretion in an osmotic diuresis. In view of the constancy of potassium and hyaluronidase output in osmotic diuresis, the effect of a potassium diuresis on hyaluronidase output was observed. However,

it was found that despite a rise in potassium excretion to 320 μequiv. per minute, there was no corresponding increase in urinary hyaluronidase.

Thus it is concluded that the mechanism of hyaluronidase excretion per minute is not directly related either to urine volume or to the excretion of sodium, potassium or total osmotically active solute.

G. M. Berlyne

Department of Medicine,
Royal Infirmary,
Manchester 13.
Oct. 28.

[1] Ginetzinsky, A. G., *Nature*, **182**, 1218 (1958).
[2] Ginetzinsky, A. G. (personal communication).
[3] Madinaveitia, J., and Quibell, T. H. H., *Biochem. J.*, **34**, 625 (1940).
[4] McLean, D., and Hale, C. W., *Biochem. J.*, **35**, 169 (1941).
[5] Dalgaard-Mikkelsen, S., and Kvorning, S. A., *Acta Pharmacol.*, **4**, 169 (1948).

Effect of Antihistamines on Mitochondrial Swelling and Liver Injury

Gallagher, Gupta, Judah and Rees[1] showed that thioacetamide, a liver carcinogen, would cause liver necrosis in rats and that a variety of antihistamines would afford protection. It was concluded that thioacetamide acted at the cell surface, but its mode of action was obscure, especially as no *in vitro* effect could be obtained. It has now proved possible to show an *in vitro* action of this compound. Liver slices, cut in the conventional manner from the livers of normal rats of the Wistar strain, show a gradual loss of certain dehydrogenases when suspended in saline solutions. Thioacetamide greatly increases this loss. Malic dehydrogenase was chosen as a suitable test system. The loss of this enzyme is shown in Table 1, which illustrates a typical experiment in the untreated slice. The effect of thioacetamide at a concentration of 0·02 *M* is shown and it can also be shown at concentrations of 5×10^{-3} *M*. These concentrations are in reasonable accord with the doses employed by Gallagher *et al.*[1], that is, 200 mgm./kgm., when it is remembered that extracellular water is of the order of 16 per cent and assuming uniform distribution of the drug.

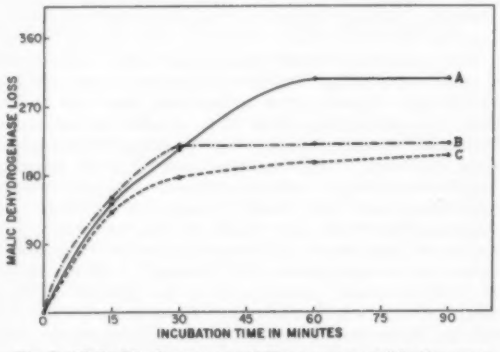


Fig. 1. Malic dehydrogenase activity was measured in the supernatant Ringer solution in which slices (about 150 mgm. wet wt.) were suspended. Samples were withdrawn as indicated and activity determined by following reduction of diphosphopyridine nucleotide spectrophotometrically. Temperature was 38°. Gas phase 95 per cent oxygen–5 per cent carbon dioxide. Dehydrogenase activity is shown in arbitrary units on the ordinates. Curve *A*, 0·02 *M* thioacetamide with calcium ion concentration 3×10^{-3} *M*; curve *B*, 0·02 *M* thioacetamide with calcium ion concentration 2×10^{-3} *M*; curve *C*, controls at both calcium-levels

The calcium-level of the medium is of importance in this action. Fig. 1 shows that reduction of the calcium-level from 3×10^{-3} *M* to 2×10^{-3} *M* results in a considerable diminution of the effect of thioacetamide. It will be seen that at both levels of calcium, the initial rates are the same but that after 30 min. the loss at the lower level is reduced to the control rate. The latter is relatively unaffected at either calcium-level. It may be inferred from this experiment that the effect of the calcium is concerned not with the initial attack of the thioacetamide, but with some subsequent step which is 'activated' by calcium, and which promotes the loss of intracellular components.

Table 1. Effect of Phenergan on Loss of Malic Dehydrogenase

Compound and concentration	Activity of malic dehydrogenase in medium as μmoles DPN reduced/100 mgm./hr. after 90 min. incubation
Nil	23·0
Thioacetamide, 0·02 *M*	40·0
Phenergan 10^{-4} *M*	24·0
Thioacetamide 0·02 *M* and phenergan 10^{-4} *M*	22·0

Liver slices (about 120 mgm. wet weight) were suspended in Krebs–Ringer, 5·0 ml., containing 0·01 *M* sodium bicarbonate with gas phase 95 per cent oxygen–5 per cent carbon dioxide. Temp. 38°. Total malic dehydrogenase activity of liver was 500 μmoles diphosphopyridine nucleotide reduced/100 mgm. liver/hr.

This interpretation is borne out by the experiments also shown in Table 1, where it will be seen that the phenothiazine antihistamine, phenergan, abolishes the effect of thioacetamide at a concentration of 10^{-4} *M*. The closely related compound chlorpromazine fails to protect these systems. Dawkins, Judah and Rees[2] have shown that phenergan prevents the accumulation of calcium in isolated perfused liver, and it may, therefore, be concluded that the action of phenergan on thioacetamide-induced leakage of malic dehydrogenase is not upon the initial attack of the drug, but upon the subsequent, calcium-'activated' step. This may also be inferred from the fact that phenergan at 10^{-4} *M* does not influence the normal rate of leakage of malic dehydrogenase from liver slices, a rate which is also uninfluenced by the calcium-levels tested, under the conditions of these experiments, but not necessarily under all conditions.

All the experiments cited above were performed in Ringer solutions buffered with sodium bicarbonate. If phosphate buffer is used at a concentration of 0·01 *M*, the action of thioacetamide on malic dehydrogenase is abolished. However, the initial attack of the drug may still be shown by following the leakage of total protein from the slices. Table 2 shows that even in phosphate buffer, loss of protein is accelerated by thioacetamide, and that this loss is unaffected by phenergan. Also shown in Table 2 is an experiment in which sodium bicarbonate is the buffer. It may be observed that a considerably greater loss of protein occurs in these circumstances and that phenergan exerts some effect. These

Table 2. Loss of Protein from Liver Slices

Compound and concentration	Mgm. protein in medium after 60 min. incubation	
	$NaHCO_3$	Phosphate buffer
Nil	5·0	3·6
Thioacetamide 0·02 *M*	8·2	5·3
Thioacetamide and phenergan 2×10^{-4} *M*	7·7	6·0
Thioacetamide and phenergan 4×10^{-4} *M*	7·3	—
Phenergan 2×10^{-4} *M*	6·3	3·6
Phenergan 4×10^{-4} *M*	6·1	—

The conditions were as in Table 1 for the experiments in sodium bicarbonate buffer; in the other experiments, phosphate buffer was added to 0·01 *M*, *p*H 7·2.

Table 3. ANTIHISTAMINES AND MITOCHONDRIAL SWELLINGS

System	Change in optical density in: 5 min.	10 min.	15 min.
Control	0·06	0·14	0·19
Phenergan 10^{-4} *M*	Nil	Nil	0·01
Benadryl 10^{-4} *M*	Nil	Nil	Nil
Pyribenzamine 10^{-4} *M*	Nil	0·03	0·03
Hispril 10^{-4} *M*	Nil	Nil	Nil

Mitochondria were suspended in 5·0 ml. 0·27 *M* sucrose–0·02 *M tris* buffer *p*H 7·2. The suspension was such that the initial reading was approximately 0·6. The changes were followed at 520 mμ on a Zeiss *PMQII* spectrophotometer.

experiments support the hypothesis that after an initial attack by thioacetamide some degradative system is set into action. This is apparently dependent upon calcium ions and is inhibited by phenergan.

The nature of the initial attack of thioacetamide is under investigation and will be reported upon in the future. The nature of the degradative system is indicated by experiments shown in Table 3 demonstrating that several antihistamine compounds inhibit swelling of isolated rat liver mitochondria. They also protect these particles against the action of calcium ions, of hypotonic solutions and of thyroxine. They do so in concentrations and conditions in which they have no effect on respiration or phosphorylation of rat liver mitochondria, and it seems clear that they inhibit some mechanism by which isolated mitochondria accumulate water. In view of the demonstration in this work that thioacetamide action on isolated liver slices is dependent upon calcium ions and that its effect is due to a primary attack followed by a degradative reaction, it is tempting to believe that the latter is in fact the swelling and disruption of the mitochondria and that this is responsible for the liver damage caused by thioacetamide *in vivo*, which is also prevented by antihistaminics. In support of this view, thioacetamide does not affect mitochondrial swelling in cell-free preparations.

The results might also indicate a general mechanism for the action of the antihistamine compounds: it could be that all permeability changes are dependent upon mitochondrial changes, and that it is these which are prevented by the drugs in any event. Histamine then would merely trigger off the change in susceptible cells, for which it is specific, as thioacetamide is for the liver.

The actions of the antihistamines will be reported in detail shortly.

This work was supported by a grant (*C*-4534) from the National Institutes of Health, U.S. Public Health Service.

J. D. JUDAH

Wistar Institute,
36th Street at Spruce,
Philadelphia. Oct. 19.

[1] Gallagher, C. H., Gupta, D. N., Judah, J. D., and Rees, K. R., *J. Path. Bact.*, **72**, 193 (1956).
[2] Dawkins, M. J. R., Judah, J. D., and Rees, K. R., *J. Path. Bact.*, **77**, 257 (1959).
[3] Judah, J. D., *Exp. Cell. Res.* (in the press).

Respiration of Decapitated Mosquitoes

THE study of the basal metabolism of mosquitoes is rendered difficult because outbursts of locomotory activity may increase the respiration many-fold. Flight increases the oxygen uptake of insects 50–100 times as compared to resting rates[1] and causes variations in respiration between different groups of mosquitoes of the same strain.

We tried to eliminate the part of respiration due to locomotory activity in females of *Aedes ægypti* L. by decapitation. Decapitated mosquitoes are entirely inactive (unless purposely stimulated), but are able to survive for more than 24 hr. if kept at room temperature at a very humid atmosphere. We also measured the respiration of female mosquitoes after removal of their halteres, as haltereless mosquitoes retain some of their activity, but flight is limited to very short periods.

The respiration of intact, haltereless and decapitated mosquitoes, was measured in a Warburg apparatus at 28° C., using 10 females per cup. Readings were taken every 15 min. for 2 hr.

The oxygen consumption of decapitated mosquitoes was close to that of intact insects and much higher than that of the haltereless ones (Table 1). This observation seemed rather surprising, since haltereless insects are more mobile than decapitated ones; we suspected that the wound created by decapitation may have increased the gas exchange. When, however, the cuts were sealed with silicone grease, the respiration of the decapitated insects did not change at all.

Table 1. OXYGEN UPTAKE OF *Aedes ægypti* FEMALES

	No. of mosquitoes used	Oxygen uptake (mm.³/hr./mosquito)
Intact mosquitoes	90	13·1±1·7*
Haltereless mosquitoes	190	8·2±0·6
Decapitated mosquitoes	190	14·7±0·9

* Standard error of the mean.

The effect of decapitation on the oxygen consumption is even better demonstrated at 12° C. At this temperature the intact insects are as immobile as the decapitated ones, and oxygen uptakes were 0·96 and 1·84 mm.³/hr./mosquito respectively. The respiration of decapitated mosquitoes is quite steady, whereas intact insects and to a lesser extent haltereless insects exhibit variations due to bursts of activity.

Only 4–5 hr. after decapitation, the respiration of the insects begins to decrease; at the end of 24 hr. it is roughly equal to the respiration of haltereless insects.

Mosquitoes which were given a blood-feed 24 hr. prior to decapitation showed a much higher oxygen uptake than decapitated insects kept previously on a sugar–water diet (17 mm.³ and 11·4 mm.³/hr./mosquito, respectively). Mosquitoes kept for 16 hr. prior to decapitation on a diet of water without sugar showed the same rate of respiration as those kept on sugar–water. Decapitation had no influence on the respiratory quotient, which was always between 0·9 and 1·1. In inactive intact mosquitoes, the spiracles are closed most of the time. Within a minute after decapitation the average spiracle aperture increases. Decapitation did not disturb the rhythm of the opening and closing of the spiracles. In mosquitoes which were decapitated while their spiracles were thus pulsating, the pulsation continued at the same rhythm, but the spiracles did not close completely. There was no increase in the ventilatory movements.

The corpora allata, which are known to influence oxygen consumption[2,3], are not removed by decapitation, but an inhibitory centre located in the head may be responsible for the increased oxygen uptake.

This increase in oxygen uptake as a result of decapitation was not observed with other insects. Raffy[4] reported that the oxygen uptake of adult silkworms decreased after decapitation, and I observed a similar effect with *Musca vicina* (Macq.) (Table 2).

Table 2. Oxygen Uptake by *Musca vicina*

	Oxygen uptake (mm.³/hr./fly)
Intact flies	59
Haltereless flies	28
Decapitated flies	14

Decapitated and intact mosquitoes respond similarly to a reduction of the oxygen tension. The experiments were again carried out in a Warburg apparatus. In all cases the total pressure was maintained at one atmosphere by replacing oxygen by nitrogen.

Both groups maintained a nearly constant uptake of oxygen even in an atmosphere containing only 3–4 per cent of oxygen. The regulation of oxygen uptake at lower oxygen tensions is achieved in mosquitoes by changes in the spiracular activity. The spiracles control oxygen uptake by staying open for longer periods, by general enlargement of the aperture, and by increasing the frequency of opening. All three phenomena were observed in decapitated mosquitoes.

I acknowledge the helpful advice of Dr. G. Fraenkel, Urbana, Ill., and technical assistance of Mrs. Hanna Jordan.

Rachel Galun

Israel Institute of Biological Research,
Ness-Ziona, Israel.

[1] Chadwick, L. E., in "Insect Physiology", 630, edit. by Roeder, K. D. (Wiley, 1953).
[2] Thomsen, E., *J. Exp. Biol.*, **26**, 137 (1949).
[3] Samuels, A., *Biol. Bull.*, **110**, 179 (1956).
[4] Raffy, A., *Ann. Physiol. Physiochim. Biol.*, **10**, 437 (1934).

A Method of controlling the Temperature of Insect Neurosecretory Cells *in situ*

Periplaneta americana, like many other animals, can maintain a 24-hr. rhythm of locomotor activity when in constant conditions of light and temperature. A secretion produced by the neurosecretory cells in the sub-œsophageal ganglion has been shown to act as a controlling factor in the regulation of the phases of this rhythm[1]. Chilling cockroaches at 3° C. for some hours causes the phases of the activity rhythm to be retarded, in relation to solar time, by the number of hours for which the temperature is lowered. A method has now been devised whereby the temperature of the neurosecretory cells of the sub-œsophageal ganglion can be maintained at 3° C., while the rest of the body remains at room temperature. Neurosecretion apparently ceases at 3° C., and the phases of the neurosecretory cycle are retarded by the number of hours for which the cells have been chilled.

Since many functions of insects are known to be affected by the activity of neurosecretory cells, this method of temperature control may be of interest to other workers.

The apparatus is shown in Fig. 1. A copper bar is cooled at one end by a small vessel filled with cold alcohol. At the other end is a hollow conical tip carrying the cooling point, a 0·4-mm. copper wire. This wire is part of a copper constantin measurement thermocouple and is coated with polystyrene. Within the hollow tip is a thermistor. By means of an electronic unit[2] the thermistor controls the current through the heater attached to the bar, and maintains the tip at a constant temperature which is higher than equilibrium value. The alcohol is held at a low temperature by thermal circulation from a sealed chamber immersed in an ice and salt mixture and contained in a lagged tank. The separation of this

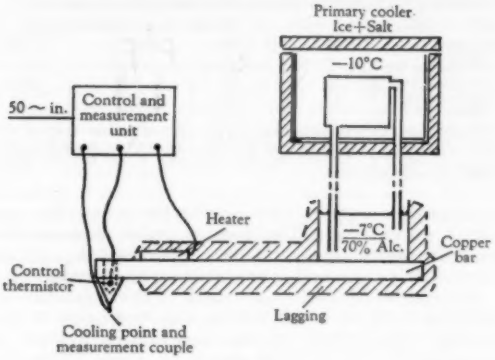


Fig. 1

primary cooler from mechanical contact with the rest of the device allows the bar to be mounted on a manipulator, and the position of the tip to be adjusted with precision.

This work was carried out as part of a programme of one of us (J. E. H.) supported by a special research grant of the Department of Scientific and Industrial Research, which is gratefully acknowledged.

R. H. J. Brown
Janet E. Harker

Zoological Laboratory,
Downing Street,
Cambridge.
Aug. 28.

[1] Harker, J. E., *Biol. Rev.*, **33**, 1 (1958).
[2] Beament, J. W. L., and Machin, K. E., *J. Sci. Instr.*, **36**, 87 (1959).

Demonstration of Serum Precipitin to Brain Ganglioside

Studies on the structure of brain ganglioside, a macromolecular glycolipid which occurs in high concentration in cerebral grey matter, suggested that this material might be suited to function at membrane surfaces, since it possesses both carbohydrate and lipid moieties structurally so arranged that the molecule could bridge hydrophylic and lipophylic phases[1]. Further investigation of the properties of this substance[2,3] demonstrated that it interacted with certain viruses, both *in vitro* and *in vivo*, in a manner suggesting that it is utilized by infecting viruses as a natural receptor substance in the cell. In a membrane-active system, the clam heart, it was found to have stimulatory effect in very low concentration[4]. The presence of hexosamine and hexose constituents in brain ganglioside relates it structurally to the blood group substances[5]. For these reasons it became of interest to determine whether antisera might be prepared to brain ganglioside.

Since this preparation of brain ganglioside does not contain amino-acid or protein components, adjuvants might have been used in initial immunization attempts. However, it was decided to attempt to obtain an antibody response to the pure substance. Rabbits were injected at weekly and monthly intervals with 0·5 mgm. of bovine brain ganglioside salt in physiological saline, the first injections being made in the toe pads of the animal, and subsequent injections being made intravenously. The presence of antibody in rabbit serum was determined by collecting blood by free drip from the marginal vein of the ear,

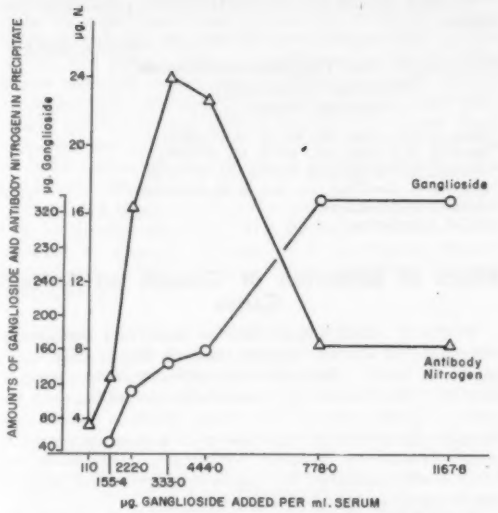


Fig. 1. Amounts of antibody nitrogen and brain ganglioside in the precipitate in the quantitative precipitin test

separating the serum, and determining the precipitin by means of the quantitative precipitin test described by Kabat[6]. The nitrogen in the precipitate was quantitatively determined by means of a Nessler's method[1]. Fig. 1 shows the results of a representative quantitative precipitin determination. In approximately one-half of the rabbits studied there was present a small amount of precipitin prior to immunization. The amount of precipitin in the serum could be increased by means of repeated injections of brain ganglioside. It may be noted that the peak of the precipitation curve is quite sharp. Because of the presence of neuraminic acid to the extent of 30 per cent by weight of the ganglioside, it was possible, by determining the neuraminic acid content, to determine the fate of ganglioside in both supernate and precipitate and thus to obtain some idea of the valence aspects of the precipitation phenomenon. The quantities in Fig. 1 are uncorrected for solubility of specific precipitate. In the zone of antibody excess, about 50 per cent of the added ganglioside is precipitated, suggesting that there is more than one immunologically distinct component in this preparation of brain ganglioside. With increasing amounts of ganglioside (into the zone of antigen excess) the precipitate contains decreasing amounts of antibody and increasing amounts of ganglioside. At the peak of the zone of maximum precipitation of antibody the precipitate contains approximately equal weights of brain ganglioside and antibody protein.

The antisera thus obtained have been used with the fluorescent antibody technique[7] to demonstrate the nerve cell body localization of brain ganglioside in bovine brain[10]. This method thus should be applicable to the histological localization of any normal or abnormal brain constituent to which antisera can be prepared.

The presence of a precipitin for brain ganglioside in mammalian serum, the titre of which is increased by successive injections of ganglioside, relates this normal brain constituent to other somatic or cellular antigens and blood-group substances immunologically as well as structurally. Other experiments in this laboratory[1-4] which have pointed to the likely membrane, transport, and receptor function of brain ganglioside are of interest in this regard. It may be that these antigenic and membrane roles are pertinently related in a manner which suggests the general function of the cellular substances which contain hexosamine or derivatives thereof (for example, muramic acid[8,9] and neuraminic acid). This function is here postulated to be the maintenance of the structural integrity and individuality of the specific cell in which they reside by the fact that their physico-chemical interaction with other molecules determines which enter and which leave the cell. Such function would have relevance to diverse biological phenomena.

These studies have been supported by grant *B*-1616 from the U.S. Public Health Service.

SAMUEL BOGOCH

Neurochemical Research Laboratory,
Department of Psychiatry,
Harvard Medical School and
Massachusetts Mental Health Center
(Boston Psychopathic Hospital).
Oct. 27.

[1] Bogoch, S., *Biochem. J.*, **68**, 319 (1958).
[2] Bogoch, S., *Virol.*, **4**, 458 (1957).
[3] Bogoch, S., Lynch, P., and Levine, A. S., *Virol.*, **7**, 159 (1959).
[4] Bogoch, S., and Bogoch, E. S., *Nature*, **183**, 53 (1959).
[6] Kabat, E. A., "Blood Group Substances, their Chemistry and Immunochemistry" (Academic Press Inc., New York, 1956).
[6] *Ibid.*, 59.
[7] Coons, A. H., and Kaplan, M. H., *J. Exp. Med.*, **91**, 1 (1950).
[8] Park, J. T., *J. Biol. Chem.*, **194**, 877 (1952).
[9] Work, E., *Nature*, **179**, 841 (1957).
[10] Bogoch, S., and Szulman, A. E. (to be published).

PLANT PHYSIOLOGY

Survival of the Twig of Woody Plants at −196° C.

I HAVE succeeded[1] in keeping alive living materials from the cell interiors of which all the easily freezable water was drawn by sufficient extra-cellular freezing at −30° C., after immersion in liquid nitrogen.

For the purpose of dehydration in various degrees, pieces from the same twig of a mulberry tree (2 cm. in length, 0·8 cm. in diameter) were pre-frozen for 16 hr. at 0°, −10°, −20°, −25°, *c.* −30° and *c.* −70° C. respectively and then immersed in liquid nitrogen. After being kept there for 10 min. they were held in air at −30° C. for 4 hr. and then transferred into air at 0° C. After this treatment the survival value of the parenchyma cells in the cortex of the twig was determined by the usual plasmolysis test. The percentage survival obtained in each case was as follows: 0 in the case of the pre-freezing at 0°, 10 at −10°, 40 to 60 at −20°, 60 to 70 at −25° and 100 at −30° to −70°. Further, in order to examine the the effect of repeated cooling, the same pieces of twig, after pre-freezing at −30° C., were immersed in liquid nitrogen for 10 min. and then were held in air at −30° C. for 1 hr. Such a process was repeated five times; but the living values were never lowered. These results indicate that if the twigs are previously frozen at −30° C., fatal intracellular freezing will never occur even at an extremely low temperature.

The same pieces of twig, after pre-freezing at −30° C., was held in liquid nitrogen for various periods of 10 min.–160 days, and the relation between the length of the immersing period and the proportion of survival was investigated. As a result

of this experiment very long immersion in liquid nitrogen for 160 days at least was found to bring about no harmful effect on the plasmolysis capacity of the parenchyma cells of the twig. In addition, a twig of a willow (*Salix koriyanagi kimura*) and a piece of twig of mulberry tree in winter were not injured even when they were cooled down from room temperature to −90° C. under a cooling rate of 0·5° C./min. without pre-freezing and were maintained at −90° to −96° C. for 2 hr. It follows, therefore, that hardy material can be continuously cooled from room temperature to super-low temperatures without damage, if cooling is done at a slow rate.

Twigs of a mulberry tree pre-frozen at −30° C. gradually suffered damage as a whole after thawing from a super-low temperature, because their inner-cortex, pith-ray and pith-periclinal tissue are less resistant to freezing at −30° C. than are the parenchyma cells of the cortex. The twigs of poplar (*Populus siebodi* Mig.) and willow (*Salix koriyanagi kimura*) (15 cm. in length, 0·8 cm. in diameter), which are completely resistant to freezing at −30° C., had been kept in liquid nitrogen for 24 hr. After thawing, they were planted in moist sand in a greenhouse to test the capacity for development. The twigs so treated normally put forth buds and rooted. Most of the twigs pre-frozen at −20° C. put forth their buds; but they gradually withered within 30–50 days after planting. Twigs tested with liquid oxygen pre-frozen at higher temperatures than −15° C. never showed any sign of development. All the twigs of a willow pre-frozen at −30° C. revived even after they had been kept in liquid oxygen for 90 days. After being planted in a greenhouse in March 1959, their new shoots were about 90 cm. long by June 1 and are still growing normally.

In this pre-freezing method, the percentage survival is scarcely affected by the rate of cooling to and re-warming from a super-low temperature if the material is previously frozen at −30° C. [2]. If the living materials can withstand pre-freezing at a temperature lower than −30° C., they might be able to survive freezing at extremely low temperature by this pre-freezing method. It can be applied to materials with less frost hardiness, if any such anti-freeze agent as a glycerol is previously used on them so that freezing at −30° C. can be resisted.

Recently, Asahina[3–5] obtained some experimental results to support the view that this pre-freezing method is remarkably effective for keeping various animals alive in liquid oxygen. He kept a slug caterpillar[3], in overwintering prepupal stage, alive in liquid oxygen, the gill pieces of the oyster (glycerin used), overwintering larvæ of a butterfly, and a plant-parasitic nematode after pre-freezing at −30° C. Nei[6] kept yeast cells, suspended in distilled water, alive in liquid nitrogen, after a pre-freezing as low as −30° C.

From these facts it seems that there is a definite temperature at which almost all the easily freezable water in a cell may be drawn from the cell interior by extracellular freezing, and that the cells and tissues in this state are not injured even when exposed to an extremely low temperature. In the case of plants and animals this temperature lies around −30° C. Below this temperature, the intensity of cold seems not to exert any important effect upon woody plants, at least as long as the intense cold does not extend over a long period, and also it seems that the low temperature itself cannot be a primary factor of damage by frost.

Further details of this work will be published elsewhere.

Akira Sakai

Institute of Low Temperature Science,
Hokkaido University,
Sapporo, Japan.

[1] Sakai, A., *Low Temp. Sci.*, Ser. B, **14**, 17 (1956).
[2] Sakai, A., *Low Temp. Sci.*, Ser. B. **16**, 41 (1958).
[3] Asahina, E., and Aoki, K., *Nature*, **182**, 327 (1958).
[4] Asahina, E., *Low Temp. Sci.*, Ser. B, **16**, 65 (1958).
[5] Asahina, E. (unpublished).
[6] Nei, T. (unpublished).

Effect of Direction of Growth on Sultana Canes

Sultana vines are pruned to a limited number of one-year-old shoots (canes), each of which may carry up to 20 buds. As canes vary greatly in the proportion of fruitful buds the pruner aims to retain only the more fruitful ones on the vine. Such a selection is possible because the appearance of a cane indicates to some extent its fruiting potential[1]. But it is not known why canes of comparable origin differ both in appearance and in fruitfulness.

It was thought that the orientation of the growing cane in the gravitational field could be one contributing factor. Strong gravimorphic response has been reported for shoots on fruit trees[2]. Investigations were therefore carried out during 1958–59 to test the effect of gravity on sultana shoots, particularly with respect to the fruitfulness of their buds.

For 12 sultana vines, growing in the field at the Commonwealth Research Station, Merbein, the normal trellis height of 4 ft. was increased by erecting a vertical wire netting trellis to a total height of 7 ft. 6 in. Two shoots each in the centre of each vine were directed vertically upwards (0°), and at angles diverging from this direction by 45°, 90°, and 120°. The shoots were trained in their respective positions from October 16, more than one month before the initiation of the first bunch primordia, until the beginning of January, when the development of at least the first 20 buds was completed on the shoots attaining that length.

In June the length of all the shoots which had matured at least three buds was measured and the number of mature buds counted. All buds to position 20 were microscopically examined for the presence of bunch primordia which were extracted and weighed on an electro-balance. The results are shown in Table 1.

In fruit trees horizontal shoots grow less and form more flowers than vertical shoots[2]. This does not apply in the sultana where fruitfulness and bunch primordium development were severely depressed when canes were diverted from their normal direction of growth. Under natural conditions sultana shoots tend to grow vertically at least until flowering during the middle of November.

The total extension growth did not differ between the canes of the four treatments, but the canes of

Table 1. Effect of Direction of Growth on Sultana Canes

	Canes deviating from the upward vertical direction by			
	0°	45°	90°	120°
No. of canes matured	16	16	9	15
Mean length of cane (cm.)	184·7	177·7	287·4	241·9
Mean internode length (cm.)	5·74	5·56	7·66	7·23*
Mean per cent fruitful buds†	39·7	44·7	17·3	20·4*
Mean bunch primordium weight (μgm.)	63·0	58·7	47·6	36·1*

* Treatments 0° and 45° differ significantly from treatments 90° and 120° in mean internode length, per cent fruitful buds, and mean bunch primordium weight.
† Statistically analysed as angular transformations.

treatments 90° and 120° had longer internodes. This could indicate that these canes were to some extent affected by being shaded for some hours daily by the rest of the vine. Heavy shading of sultana vines causes not only extension of internode length but it also reduces fruitfulness[3]. In treatments 90° and 120° bunch initiation and development may have been somewhat inhibited by the shading, but this was far too light to nullify any effect of gravimorphism such as found in fruit trees.

One could speculate that the grape vine differs from fruit trees and also from the Japanese larch[4] in its reaction to gravity because it is a climber under natural conditions. This problem may bear further investigation.

P. May

Commonwealth Scientific and Industrial Research Organization,
Commonwealth Research Station,
Merbein, Victoria.
Oct. 6.

[1] Antcliff, A. J., Webster, W. J., and May, P., *Aust. J. Agric. Res.*, **9**, 328 (1958).
[2] Wareing, P. F., and Nasr, T., *Nature*, **182**, 379 (1958).
[3] May, P., and Antcliff, A. J. (unpublished results).
[4] Longman, K. A., and Wareing, P. F., *Nature*, **182**, 380 (1958).

Effect of Gibberellic Acid on Seeded Grapes

Size of grape berries was found by Müller-Thurgan in 1898 to be correlated with its number of seeds[1]. Size of seedless berries could be increased by means of auxins such as *p*-chlorophenoxyacetic acid[2,3] and by gibberellin spray[4,5]. The sprays had, however, no effect on size of seeded grapes[6,7].

Bunches of 'Queen of Vinyard' grapes were sprayed about 23 days after full bloom with 20 p.p.m. α-naphthalene acetic acid and gibberellin, respectively; 0·1 per cent 'Triton *X*-100' was added as wetting agent. 'Triton' alone was used for the controls. The fruit was harvested at full maturity, weighed, cut in halves and the number of seeds determined.

Results in Table 1 show a correlation of size of fruit and number of seeds. The 20 p.p.m. α-naphthalene acetic acid had no effect on fruit size; gibberellin, on the other hand, showed a marked effect. The added weight, however, decreased with the increasing number of seeds.

Table 1. Effect of Growth Substances on Grape Berries containing Different Numbers of Seeds. (Weight of 100 Berries in gm.)

Treatment	Seed No. per berry 0	1	2	3
Control	19	349	465	523
α-Naphthalene acetic acid	81	355	457	533
Gibberellin	181	491	506	526

This decrease is shown more clearly in the ratio between the weight of treated and untreated berries as affected by number of seeds (Fig. 1). The curve indicates that while the ratio is about 2·5 with parthenocarpic fruit it approaches 1 when the number of three seeds is reached.

It can be concluded, therefore, that gibberellin has a physiological effect on seeded berries, but only to a limited extent. Gibberellin compensates for the 'lack' of seeds; but once the berry has a sufficient number of seeds, gibberellin at the concentration used had no further effect.

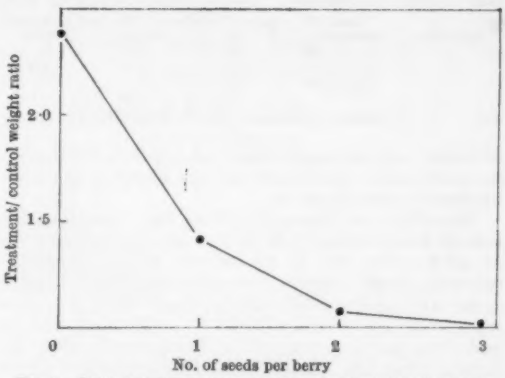


Fig. 1. Ratio between weight of gibberellin-treated and control grape berries as affected by number of seeds

No seed-like formations were found in the fruit due to gibberellin, though the tissue was more firm at the missing seed locations. α-Naphthalene acetic acid showed no effect.

S. Lavee

Division of Pomology and Viticulture,
Agricultural Research Station,
Rehovot,
Israel.

[1] Müller-Thurgan, M., "Land W. Ib. Schweiz", 135 (1898).
[2] Coombe, B. C., *South Austral. J. Agric.*, **57**, 107 (1953).
[3] Weaver, R. J., *Proc. Amer. Soc. Hort. Sci.*, **61**, 135 (1953).
[4] Stewart, W. S., Ghing, F. T., and Halsey, D. D., *Lasca Leaves*, **7**, 80 (1957).
[5] Weaver, R. J., and McCune, S. B., *Hilgardia*, **27**, 189 (1957).
[6] Samish, R. M., and Lavee, S., *Agric. Res. Sta. Rehovot 'Klavim'*, **8**, 273 (1958).
[7] Weaver, R. J., and Williams, W. O., *Bot. Gaz.*, **113**, 75 (1951).

Mutagenic Action of Mitomycin *C* on *Escherichia coli*

Mitomycin *C* is of biological interest not only because it selectively inhibits cellular deoxyribonucleic acid synthesis[1,2] but also in that it induces lambda phage development in *Escherichia coli K* 12[3].

In this communication we present evidence that mitomycin *C* also affects the genetic mechanism, such as exerting a mutagenic action and stimulating the recombination rate in *Escherichia coli*.

Mutagenic action of mitomycin *C* was demonstrated in the reversion of *Escherichia coli B/r* tryptophan-requiring strain to the wild type. Logarithmic growing cells of this strain were harvested by centrifugation and resuspended in glucose-salt medium containing mitomycin *C* at a concentration of 1 μgm./ml. and incubated at 37° for 15 min. After the agent was removed by centrifugation, a part of the treated cell suspension was plated both on nutrient medium and minimal medium in order to count the total number of viable cells and the revertants to the wild type, immediately after the treatment. Another part of the treated cell suspension was incubated in broth after the treatment and assayed by the same method after one hour incubation.

During the treatment with mitomycin *C* the total number of viable cells decreased to one-tenth of the initial but during the post-incubation in broth the number of viable cells remained constant. Immediately after the treatment with mitomycin *C* the ratio of number of prototroph colonies to the total number

Table 1. Effect of Mitomycin C on the Yield of the Wild Type

Exp. No.	Conc. of mitomycin C	Time of incubation after the treatment 0	30 min.	60 min.
1	1 μgm./ml.	36*	90	77
	0	1·2	1·5	0·3
2	1 μgm./ml.	25	182	177
	0	1·8	1·9	1·3

* Number of revertants per 10^8 viable cells.

of viable cells increased about tenfold of spontaneous reversion ratio. Much increase was found in the post-incubated cells (Table 1).

The effect of mitomycin *C* on the recombination rate of *Escherichia coli K* 12 was also examined. Cells of *Escherichia coli K* 12 58–161 *F*+ methionine-requiring strain were treated with mitomycin *C* in the same way as described above. The treated *F*+ cells were crossed with cells of *Y*–70 *F* − threonine, leucine and thiamine requiring strain, immediately after the treatment or 1 hr. incubation in broth followed by the treatment.

The ratio of prototrophic recombinants to the total viable cells was also increased five- to ten-fold and a greater enhancement was confirmed in the post-incubated sample. The reciprocal treatment of the recipient *F*− cells was ineffective to increase this ratio. The question remains as to whether the donor cells which lost their ability to form colony by the treatment with mitomycin *C* retain their capability to donate their chromosome.

These effects of mitomycin *C* on *Escherichia coli* obtained here were very similar to those due to ultra-violet radiation.

We are indebted to Prof. H. Kikkawa for his suggestions and criticism, and to Dr. S. Shiba for his generous supply of mitomycin *C*. We also wish to express our appreciation of the suggestion and encouragement given by Prof. Y. Takagi in Kanazawa University. This work was supported in part by a grant from the Ministry of Education.

Teiji Iijima
Atsuyoshi Hagiwara

Department of Genetics,
Medical School, Osaka University,
and Department of Biology,
Faculty of Science,
Osaka University, Osaka,
Japan.

[1] Shiba, S., Terawaki, A., Taguchi, T., and Kawamata, J., *Nature*, **183**, 1056 (1959).
[2] Sekiguchi, M., and Takagi, Y., *Nature*, **183**, 1134 (1959).
[3] Otsuji, N., Sekiguchi, M., Iijima, T., and Takagi, Y., *Nature*, **184**, 1079 (1959).

HÆMATOLOGY

In vitro Synthesis of Fœtal and Adult Hæmoglobin by Fœtal Hæmatopoietic Tissues

The demonstration of a biochemical distinction between adult and fœtal forms of hæmoglobin (hæmoglobins *A* and *F*) has stimulated interest in their physiology and biochemistry[1]. Little is known about the site of origin or conditions governing the production of these two hæmoglobins. It has been postulated that hæmoglobin *A* is synthesized in the bone marrow and that hæmoglobin *F* is produced principally in the liver and spleen[2,3]. This theory corresponds well with the known sites of red cell production in the fœtus and in the adult[3]. As a corollary, it has been proposed that hæmoglobin *A* and hæmoglobin *F* occur in separate red cells[2,4]. Anoxia has been thought to increase the production of hæmoglobin *F*[4]. This report presents a study of the synthesis of hæmoglobins *A* and *F* by hæmatopoietic tissue from two white human fœtuses aged 17 and 9 weeks.

A viable fœtus of 17 weeks gestation (by menstrual history) was obtained immediately after surgical removal. Cell suspensions (approximately 100×10^6 nucleated cells per aliquot) were prepared from liver, spleen and bone marrow[5]. The cells were incubated for 24 hr. in 2 ml. of 50 per cent adult serum (type *AB*) in Hanks's solution (*p*H 7·6) containing 125 μgm. (2·7 μc.) of glycine-2-^{14}C. The percentages of oxygen in the gas phase during incubation are shown in Table 1. At the end of incubation the cells were washed three times with saline, and an excess of carrier hæmoglobin was added. The carrier contained 60 mgm. of hæmoglobin *A* and 60 mgm. of hæmoglobin *F*, prepared as a mixture of adult and cord blood. The alkali denaturation procedure[6] was used to determine the amount of hæmoglobin *F* in the cord blood. The samples were converted to carboxy-hæmoglobin, and the adult and fœtal fractions were separated on an ion exchange column (1 × 10 cm.) using 'Amberlite *IRC*-50 (*XE* 64)' with a sodium citrate buffer at *p*H 6·5 as described by Prins and Huisman[7]. The separated hæmoglobins were dialysed for 48 hr. against distilled water, dried and counted at infinite thickness in a flow gas counter.

The results of the experiment are shown in Table 1. The measurements presented do not support the postulation of separate organ sites for the production of adult and fœtal hæmoglobins[2,3]. Relatively more hæmoglobin *F* was produced by cells from liver and spleen than from bone marrow, but the bone marrow of this fœtus produced twice as much hæmoglobin *F* as hæmoglobin *A*.

Anoxia did appear to induce a relative increase in the proportion of hæmoglobin *F* as compared to hæmoglobin *A*. However, it should be pointed out that the synthesis of both hæmoglobins decreased with decreasing oxygen tension.

Table 1 also shows a comparable experiment using the liver of a fœtus of 9 weeks gestation. Radioactivity indicating hæmoglobin synthesis was found both in the adult and in the fœtal fraction and in a proportion of about 1 part adult to 2 parts fœtal.

Walker and Turnbull[4] reported that hæmoglobin *A* is absent from fœtal blood until the 13th week of gestation. In the experiment shown in Table 1, hæmoglobin *A* was actively synthesized in the liver of the fœtus of 9 weeks gestation. Since synthesis of hæmoglobin *A* in hæmatopoietic cells must begin before significant amounts appear in the blood, the observations of Walker and Turnbull are not

Table 1. Radioactivity of Hæmoglobin expressed as Counts per Minute at Infinite Thickness

Exp.	Oxygen Per cent	Liver Hb-*A* c.p.m.	Liver Hb-*F* c.p.m.	Liver Hb-*A*/Hb-*F*	Spleen Hb-*A* c.p.m.	Spleen Hb-*F* c.p.m.	Spleen Hb-*A*/Hb-*F*	Bone marrow Hb-*A*	Bone marrow Hb-*F*	Bone marrow Hb-*A*/Hb-*F*
A	20 (air)	535	2600	1/4·8	47	189	1/4·0	465	870	1/1·8
	10	372	1950	1/5·3						
	5	101	816	1/8·0						
	0	29	55							
B	20 (air)	1280	2940	1/2·3						

Exp. A, 17 week fœtus, crown-rump measurement 13 cm. ; Exp. B, 9 week fœtus, crown-rump measurement 2·1 cm.

necessarily incompatible with those here reported. At a given time the ratio of synthesis of hæmoglobin *A* to hæmoglobin *F* must be greater than the ratio of these two hæmoglobins in the blood due to the life-span of the red cells, to the increasing percentage of hæmoglobin *A* and to the expanding blood volume of the fœtus. Should fœtal red cells containing hæmoglobin *A* have a relatively shorter life-span than those containing hæmoglobin *F*, the synthetic ratio, *A*/*F*, might be even higher. However, our observations do not bear upon the question of whether separate red cells contain exclusively one or the other types of hæmoglobin[3,4].

We have assumed the presence of only two hæmoglobins, *A* and *F*. It is now generally recognized that these two fractions are heterogeneous[5]. Experiments to characterize these hæmoglobin subfractions and to evaluate their importance in hæmoglobin synthesis are in progress.

This work was supported by a grant (*C*-2643) from the United States Public Health Service. Two of us (H. L. L., jun., and W. B. G., III) received financial aid as Public Health Service Research Fellows, National Institutes of Health, Bethesda, Maryland.

E. Donnall Thomas
Harry L. Lochte, jun.
William B. Greenough, III
Marion Wales

Mary Imogene Bassett Hospital
(affiliated with Columbia University),
Cooperstown, New York.
Aug. 31.

[1] White, J. C., and Beaven, G. H., *Brit. Med. Bull.*, **15**, 33 (1959).
[2] Langley, F. A., *Arch. Dis. Childhood*, **26**, 64 (1951).
[3] Brody, S., *Lancet*, **1**, 520 (1959).
[4] Walker, J., and Turnbull, E. P. N., *Arch. Dis. Childhood*, **30**, 111 (1955).
[5] Thomas, E. D., *Blood*, **10**, 600 (1955).
[6] Jonxis, J. H. P., and Visser, H. K. A., *Amer. Med. Assoc. J. Dis. Children*, **92**, 588 (1956).
[7] Prins, H. K., and Huisman, T. H. J., *J. Lab. and Clin. Med.*, **46**, 255 (1955).
[8] Allen, D. W., Schroeder, W. A., and Balog, J., *J. Amer. Chem. Soc.*, **80**, 1628 (1958).

Plasma Antihæmophilic-Factor Concentrations in the Australian Aborigine and in Conditions associated with Hyperglobulinæmia

While studying the plasma antihæmophilic-factor concentrations of a large number of healthy individuals, it was noted that Australian aborigines in general have higher plasma concentrations of this factor than the white Australian population. The factor was estimated by a technique[1] based on the thromboplastin generation test and results were expressed as a percentage of the concentration in a standard normal plasma. The lower histogram in Fig. 1 shows the plasma concentrations in 86 healthy white adults adjusted to the nearest 10 per cent. The values are skewed with a fairly sharply defined lower limit and range from 60 to 200 per cent of standard normal. This group comprised equal numbers of males and females, and there was no significant sex difference in the values. These normal results are very similar to those found in a previous group of 80 normal white adults reported on from this laboratory[2].

Concurrent with the examination of this normal group, blood samples were examined from 28 Australian aborigines who were hospital in-patients.

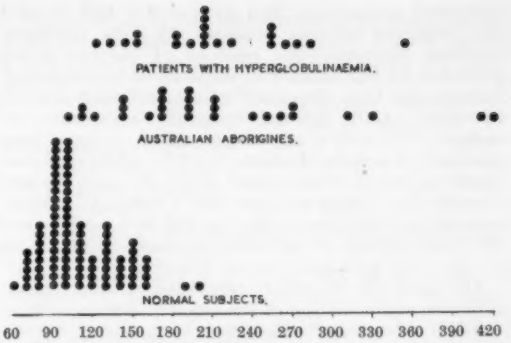

PATIENTS WITH HYPERGLOBULINAEMIA.
AUSTRALIAN ABORIGINES.
NORMAL SUBJECTS.
60 90 120 150 180 210 240 270 300 330 360 390 420
Plasma antihæmophilic-factor concentration (per cent standard normal)

Fig. 1. Plasma antihæmophilic-factor concentrations in normal subjects, Australian aborigines and patients with hyperglobulinæmia

The plasma antihæmophilic-factor concentrations are shown in the middle histogram in Fig. 1. Values ranged from 100 to 420 per cent of standard normal and twelve samples showed values greater than the upper limit of the normal white range. The natives were of mixed purity from half caste to full blood. They were in hospital mostly for surgical or traumatic reasons. The higher values could be the result of different racial origin. However, the Australian aborigine has a higher concentration of plasma γ-globulin than the white Australian[3]. It was therefore decided to investigate white Australians who had hyperglobulinæmia as the result of disease.

The upper histogram in Fig. 1 shows the plasma antihæmophilic-factor concentrations in 22 white Australians who had hyperglobulinæmia as a result of varying diseases including lymphosarcoma, autoimmune disease, hepatic cirrhosis, nephrosis and multiple myelomatosis. Values ranged from 120 to 350 per cent of standard normal and approximated more to the aboriginal group than the white normal group. Nine samples showed values greater than the upper limit of the white normal range.

The plasma antihæmophilic-factor value is thought to be genetically determined and constant for the individual. The findings in the patients with hyperglobulinæmia indicate that the value can alter with disease. That plasma antihæmophilic-factor concentration may be related to the γ-globulin concentration is unexpected since the antihæmophilic-factor migrates electrophoretically with fibrinogen.

W. R. Pitney
M. H. Elliott

Department of Hæmatology,
Royal Perth Hospital,
Western Australia.

[1] Pitney, W. R., *Brit. J. Hæmat.*, **2**, 250 (1956).
[2] Pitney, W. R., and Arnold, B. J., *Brit. J. Hæmat.*, **5**, 184 (1959).
[3] Curnow, D. H., *Med. J. Aust.*, ii, 608 (1957).

Absorption–Elution Grouping of Dried Blood Smears

Thick blood smears (5–10 μl./cm.²) can be grouped in the ABO blood group system by an absorption-elution technique which has been evolved in this Laboratory over the past two years.

Dried blood smears, on standard microscope slides, prepared in the usual way, are fixed by plunging in *p*H 7·4 McIlvane buffer at 100° C. for 30 sec. The

denatured smears are then blotted dry and divided into separate cavities bounded by gum dammar/beeswax mixture[1], the number of cavities being governed by the number of antisera to be employed. Antisera are then dispensed into the relevant cavities in excess of the amount required to saturate the antigen. The slide is allowed to stand at room temperature, in a moist chamber, for 3 hr. with occasional gentle agitation, then rinsed under the cold tap and blotted dry. Drops of 2 per cent v/v red cell suspension are next dispensed into the different cavities and the temperature of the slide is raised to 50° C. for 5 min. in a preheated moist chamber.

On removal to room temperature, and gentle rotation, agglutination of the red cells occurs in those cavities where antibodies have been eluted by the elevated temperature.

Typical results obtained are shown in Table 1.

Table 1

Group of blood smear	Antiserum and cells added: Anti-A A_1	Anti-A_1 A_1	Anti-B B	Group O A_1	Group O B	Gorse Anti-H O
A_1	+	+	−	+	±	−
A_2	+	−	−	+	±	+
B	−	−	+	±	+	±
O	−	−	−	−	−	+
A_1B	+	+	+	+	+	−
A_2B	+	−	+	+	+	+

+, Macroscopic agglutination; ±, variable results; −, no agglutination.

The agglutination is, in nearly all cases, visible to the unaided eye, although with some thinner blood smears microscopic examination may be necessary. Using group O antiserum, an A blood smear (especially if very thick) may elute anti-B and conversely a group B blood smear may elute anti-A. This is in agreement with the results obtained from antibody elution from intact cells[2]. Gorse extract is a source of potent and specific anti-H [3] while the anti-A_1 antiserum used is pooled group B absorbed with A_2 cells. The appearance of a slide bearing a smear of A_2 blood on completion of grouping by the above technique is shown in Fig. 1.

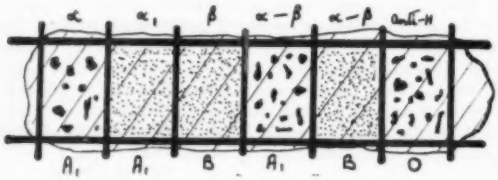


Fig. 1

The anti-A and anti-B sera used (cols. 1 and 3) have given unequivocal results in all tests we have made. The group O serum reactions (cols. 4 and 5) have given consistently weaker reactions than separate anti-A and anti-B, but we have included it as a check and as being of possible significance when testing for subgroups of A weaker than A_2. The anti-A_1 and anti-H reactions have in most cases given good reciprocal results.

The technique has obvious uses in the field of blood grouping, particularly since we have recently found that it can be applied to smears made from dried bloodstains. The advantages are that no antisera of standardized titre are required, no interference by detergents is encountered (these are extracted by the hot water) and the results can be read immediately without tedious pipetting and microscopic examination. The smears can be stored indefinitely and repeat grouping can simply be made by rinsing the cells and antibodies off the slide with water at 50° C. and starting again as with a freshly fixed blood smear.

The method shows obvious promise, and merits further investigations to an extent which is not possible in a routine laboratory. These preliminary observations are published in the hope that research workers in blood group serology will take the study further.

I am indebted to Dr. I. Dunsford for criticism, antisera and blood samples, and to Dr. I. M. Barclay, director of this Laboratory, for permission to publish this communication.

S. S. Kind

Home Office
Forensic Science Laboratory,
32 Rutland Drive,
Harrogate, Yorkshire.

[1] Dade, H. A., and Waller, S., Commonwealth Mycological Papers No. 27 (1949).
[2] Dodd, B. E., *Brit. J. Exp. Path.*, **33**, 1 (1952).
[3] Boyd, W. C., and Shapleigh, E., *J. Lab. Clin. Med.*, **44**, 235 (1954).

RADIOBIOLOGY

Evidence for Protein Turnover in an Embryonic System

In a previous communication we have compared the relative efficiency of various proteins, peptides and free amino-acids as precursors of chick embryonic proteins[1]. From these studies we concluded that during the early stages of development the preferred precursor was yolk protein (rather than peptides or amino-acids) and that the pathway of synthesis of chick embryonic protein probably proceeded via a stage involving amino-acid derivatives (possibly amino acyl adenylates[2] or, more likely, amino-acids linked to the terminal adenosine residues of polyribonucleotides[3–6]).

In the present study we investigated the utilization by chick embryos of intravenously injected sulphur-labelled protein precursors in the formation of heart and liver, as well as the relative rates of growth of these organs, as indicated by the uptake of label by these organs.

Torulopsis utilis was grown on sulphate labelled with sulphur-35 according to the method of Wood and Perkinson[7]. After extraction with organic solvents[8], the yeast protein was hydrolysed with a 1:1 mixture of 6 *N* hydrochloric acid and 90 per cent formic acid. The humin was removed by centrifugation, and a portion of the neutralized hydrolysate corresponding to about 1 mc. of the original labelled sulphate per 30 gm. body-weight was injected intraperitoneally into a White Leghorn hen. In other experiments cystine labelled with sulphur-35 was removed from the yeast protein hydrolysate by adding carrier cystine, and precipitating this amino-acid at *p*H 4·5 in the cold overnight. This cystine-free yeast protein hydrolysate was then injected into baby chicks. Eight to twelve hours after injection the animals were bled by heart puncture, and serum albumin and serum albumin peptides were prepared by methods previously described[9]. Embryonated White Rock eggs were incubated at 38°C. under conditions of controlled humidity for a period of 9 days. Embryos were injected intravenously[10]

with one of the following protein precursors on the ninth day of incubation: yeast protein hydrolysate containing either methionine labelled with sulphur-35 alone or containing both labelled methionine and labelled cystine; chicken serum albumin peptides containing sulphur-35 in the methionine residues or containing sulphur-35 in both the methionine and cystine residues; or chicken serum albumin containing labelled methionine. It should be pointed out that all preparations also contained some labelled methionine sulphoxide[9]. On the tenth day of incubation hearts and livers were excised[10], the organs pooled and homogenized, and dry protein powders prepared for counting[9]. The results of these experiments are shown in Table 1.

Table 1. Distribution of Label in Embryonic Chick Heart and Liver on the Tenth Day of Incubation after Intravenous Injection of Various Protein Precursors on the Ninth Day of Incubation

Precursor Injected	Per cent injected activity		Specific activity (Heart/Liver)
	Heart	Liver	
Yeast hydrolysate containing labelled methionine	0·62	1·61	1·30
Yeast hydrolysate containing labelled methionine and labelled cystine	0·55	1·62	1·08
Chicken serum albumin peptides containing sulphur-35 in the methionine residues	0·62	1·62	1·18
Chicken serum albumin peptides containing sulphur-35 in the methionine and cystine residues	0·55	1·66	1·23
Chicken serum albumin containing labelled methionine	0·46	1·77	1·20
	0·56	1·48	1·37
	0·35	1·23	1·50
	0·12	0·40	1·24
	0·29	0·56	1·95

The results are presented here in two ways: as the percentage of injected activity found in the two organs for each of the precursors injected, and as the ratio of specific radioactivity of heart/liver. The values indicating the percentage of injected activity are uniformly larger for liver than heart, as is expected on the basis of the difference in size of the two organs on the tenth day of development. It will be noticed, however, that all the values (independent of the type of protein precursor injected) for embryonic heart are quite close to one another, as are the values for embryonic liver.

These results indicate that while anabolism is certainly the predominant process in this rapidly proliferating system, some catabolic capacity must also be operative in order to account for the conversion of injected serum protein and peptides into embryonic tissues. This is in contrast to the finding that catabolism does not take place in rapidly growing bacterial systems[11,12], but corresponds more closely to the situation in resting bacterial suspensions where protein turnover is known to take place[13]. We had previously suggested[1] that in the conversion of yolk protein to embryonic chick protein the catabolic activity was centred in the yolk[14] while the synthetic activity resided in the embryo proper. The present results do not conflict with this conclusion but indicate that the embryonic system itself does contain a catabolic potential.

The ratio of specific radioactivity of heart/liver is also shown in Table 1 and is uniformly greater than 1·00. This indicates that both organs are capable of incorporating each of the various protein precursors tested at essentially similar rates; furthermore, over the period of the experiment the heart is anabolically more active than the liver (that is, within the time period tested a greater fraction of its newly synthesized protein has its origin in the precursors supplied).

One of us (H. R. M.) was supported by grants-in-aid from the National Heart Institute, United States Public Health Service (No. *H*-2177) and Eli Lilly and Co.

Harry Walter*
H. R. Mahler

Department of Chemistry,
Indiana University,
Bloomington, Indiana.
Oct. 2.

* Present address: Radioisotope Service, Veterans Administration Hospital, Brooklyn, New York.

1 Walter, H., and Mahler, H. R., *J. Biol. Chem.*, **230**, 241 (1958).
2 Hoagland, M. D., Keller, E. B., and Zamecnik, P. C., *J. Biol. Chem.*, **218**, 345 (1956).
3 Schweet, R. S., Bovard, F. C., Allen, E., and Glassman, F., *Proc. U.S. Nat. Acad. Sci.*, **44**, 173 (1958).
4 Zachau, H. G., Acs, G., and Lipmann, F., *ibid.*, **44**, 885 (1958).
5 Preiss, J., Berg, P., Ofengand, E. J., and Bergman, F. H., *ibid.*, **45**, 319 (1959).
6 Hecht, L. I., Stephenson, M. C., and Zamecnik, P. C., *ibid.*, **45**, 505 (1959).
7 Wood, J. L., and Perkinson, J. D., *J. Amer. Chem. Soc.*, **74**, 2444 (1952).
8 Williams, R. B., and Dawson, R. M. C., *Biochem. J.*, **52**, 314 (1952).
9 Walter, H., Haurowitz, F., Fleischer, S., Lietze, A., Cheng, H. F., Turner, J. E., and Friedberg, W., *J. Biol. Chem.*, **224**, 107 (1957).
10 Walter, H., Allmann, D. W., and Mahler, H. R., *Science*, **124**, 1251 (1956).
11 Spiegelman, S., in "Enzymes, Units of Biological Structure and Function", ed. by Gaebler, O. H. (Academic Press, 1956).
12 Hogness, D. S., Cohn, M., and Monod, J., *Biochim. Biophys. Acta*, **16**, 99 (1955).
13 Reviewed by Pollock, M. R., in "The Enzymes", 2nd ed. (ed. by P. D. Boyer, H. A. Lardy, and K. Myrback) (Academic Press, New York, 1959).
14 Romanoff, A. L., *Ann. N.Y. Acad. Sci.*, **55**, 288 (1955).

Ear Tumours in Rabbits receiving Strontium-90

The induction of bone tumours by radium and other 'bone-seeking' radioactive materials is now well known. It was originally observed in human cases of radium poisoning[1–4]. Experimentally, similar tumours have been produced in a wide range of animal species following the administration of either radium[5–9] or a variety of 'bone-seeking' radioactive isotopes such as strontium-89, strontium-90, plutonium-239 and calcium-45[10–19]. Tumours occur in the neighbourhood of sites of maximum isotope deposition and retention (see ref. 13). In young rabbits receiving a single injection of strontium-90[13], tumours occurred most frequently in the metaphysial regions of the long bones, while in both old and young rabbits[20] they occurred adjacent to growing teeth in the mandible and maxilla.

Less well known are the tumours of soft tissues adjacent to bone which occasionally develop in the same circumstances. Among their cases of radium poisoning, Aub *et al.*[4] reported three examples of epidermoid carcinoma arising in the nasal accessory sinuses or in the temporal bone. Koletsky *et al.*[12] noted squamous cell carcinoma of the nasal region of rats following the administration of phosphorus-32. Kuzma and Zander[18] observed similar squamous cell carcinomas in rats following the administration of strontium-90 (but not in rats receiving calcium-45), and Finkel, Biskis and Scribner[21] have observed similar tumours in mice receiving strontium-90. The present communication directs attention to the occurrence of tumours of the epithelium of the external auditory meatus in certain groups of rabbits receiving strontium-90.

In a study of the effect of a single injection of high dose of strontium-90 (500–1,000 μc./kgm.) in rabbits[13],

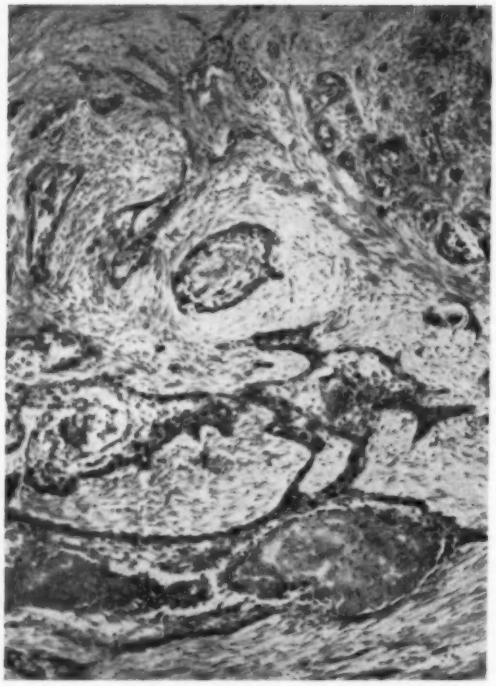


Fig. 1. Squamous cell carcinoma invading soft tissues near temporal bone. (× 66)

it was noted that three of a litter of four rabbits injected with 500 μc./kgm. at the age of 2 days developed symptoms, about 6 months later, attributed to a lesion of the vestibular apparatus. The rabbits were extremely unsteady in gait, they tended to fall over, and carried their heads on one side. Gross examination of the skull and the brain failed to show any obvious abnormalities, except that the external auditory meatus appeared to be blocked with inspissated wax. This proved sterile on culture. The skulls were unfortunately lost before histological examination was made.

A second litter of 4 new-born rabbits, injected with 500 μc./kgm. at 2 days of age, has now been studied. These rabbits all died after a period of 14–22 months: they failed to show evidence of bone damage or tumour formation in the peripheral skeleton, but

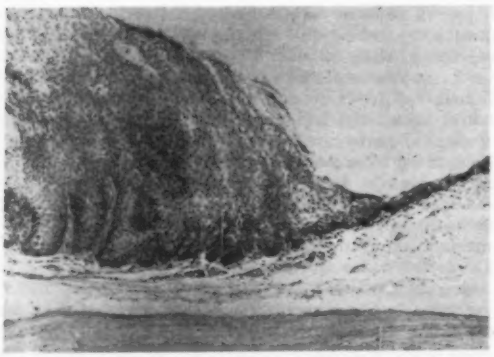


Fig. 2. Thickened (possibly carcinomatous) epithelium in external auditory meatus. (×50)

they presented the same symptoms of ear disease that were noted in the first group. Examination of the external auditory meatus showed that it was occupied by a mass of friable dark wax-like material: histological examination showed the lesions to be squamous carcinomas of the external auditory meatus. In two of the rabbits, invasive squamous cell carcinomas (Fig. 1) of the external auditory meatus were present in each ear: in the remaining two, one ear showed an invasive carcinoma while the other showed a diffuse thickening of the epithelium (Fig. 2) which is regarded as a carcinoma *in situ*. The invasive tumours extended to the soft tissues surrounding the ear, the temporal bone and the cavities of the middle ear.

Table 1

	Dose (μc./kgm. ^{90}Sr)	Survival (months)	Bone tumours	Right ear	Left ear
New-born rabbits					
801*a*	500	7	—	Symptoms of ear disease	
801*c*	500	7	—		
801*d*	500	6	—		
801*b*	500	17	—	No obvious abnormality	
888*a*	500	15	—	Carcinoma	Thickened
888*b*	500	22	—	Carcinoma	Carcinoma
888*c*	500	16	—	Carcinoma	Carcinoma
888*d*	500	15	—	Carcinoma	Thickened
Weanling rabbits					
908	200	19	—	Normal	Normal
909	200	27	—	Carcinoma	Thickened
910	200	24	—	Normal	Carcinoma
802	600	7	++	Thickened	Thickened
902	600	9	++	Carcinoma	Thickened
1-year rabbits					
823	200	19	—	Normal	Normal
870	300	27	—	Normal	Normal
868	400	34	++	Normal	Normal
859	500	24	+	Normal	—
865	500	8	+	Normal	—
807	1,000	7	+	Normal	Normal
847	1,000	6	—	—	Normal
857	1,000	6	+	Normal	—
864	1,000	6	+	Normal	Normal

In order to determine whether epithelial tumours develop in the ears of older rabbits injected with strontium-90, we have examined histological sections from the temporal bones of two other groups of animals (Table 1). The first of these consisted of 5 rabbits injected at the age of 6–8 weeks. Three of these each received 200 μc./kgm. strontium-90 and lived for 19–27 months (908, 909, 910). In two of these animals (one of which had symptoms similar to those present in the previous groups) one ear showed an invasive squamous cell carcinoma of the external auditory meatus, while in the third the epithelium of the external auditory meatus was not abnormal. The two remaining weanling rabbits received 600 μc./kgm. strontium-90 each (802, 902). One, killed at 9 months, had an invasive squamous cell carcinoma of the external auditory meatus on one side and proliferative apparently neoplastic change on the other; the other, killed at 7 months, showed irregular and apparently neoplastic thickening of the epithelium of the external auditory meatus on each side, although no invasive tumour was present.

The second group consisted of 9 rabbits injected at the age of one year with doses of 200–1,000 μc./kgm., and dying 6–34 months later. None of these animals presented symptoms of ear disease, and in none of them were histological abnormalities of the external auditory meatus found.

Spontaneous tumours in this situation do not appear to have been reported in rabbits. It would appear likely that the tumours in the experimental animals resulted from irradiation of the epithelial tissue from strontium-90 deposited in the surrounding and immediately adjacent bone, although the changes we have regarded as carcinoma *in situ* sometimes

extend to the epithelium of the outer part of the external auditory meatus at some distance from the temporal bone. In such a situation, the mechanism of tumour induction is not clear: perhaps some migration of the epithelial tissue occurs during growth and development, or the uptake and retention of strontium-90 or its decay product yttrium-90 in other tissues, such as the adjacent cartilage of the pinna, may be concerned.

It is perhaps significant that in the weanling rabbits a number of the ear tumours occurred in animals that had survived longer than others of the same series in which bone tumours had developed, and it may be that the development of malignant change in epithelial tissues adjacent to bone takes longer than in bone itself. In this connexion, it is interesting to note that 2 of the 3 epidermoid carcinomas of nasal accessory sinuses reported by Aub *et al.*[4] in human radium poisoning developed as long as 33 years after exposure to radium, while periods of 15–18 years were concerned with the 6 bone sarcomas reported in the same series.

The retention of strontium-90 and yttrium-90 in the temporal bone and the cartilage of the pinna is being studied further.

H. A. Sissons

Institute of Orthopædics,
University of London.

Janet Vaughan

M.R.C. Group for Research on
Bone-seeking Isotopes,
Churchill Hospital, Oxford.
Oct. 27

[1] Martland, H. S., *Amer. J. Cancer*, **15**, 2435 (1931).
[2] Looney, W. B., and Woodruff, L. A., *Arch. Path.*, **56**, 1 (1953).
[3] Looney, W. B., Hasterlik, R. J., Brues, A. M., and Skirmont, E., *Amer. J. Roentgenol.*, **73**, 1006 (1955).
[4] Aub, J. C., Evans, R. D., Hempelmann, L. H., and Martland, H. S., *Medicine*, **31**, 221 (1952).
[5] Sabin, F. R., Doan, C. A., and Forkner, C. E., *J. Exp. Med.*, **56**, 267 (1932).
[6] Schürch, O., and Uelinger, E., *Arch. klin. Chir.*, **183**, 704 (1935).
[7] Hellner, H., *Arch. klin. Chir.*, **189**, 706 (1937).
[8] Dunlap, C. E., Aub, J. C., Evans, R. D., and Harris, R. S., *Amer. J. Path.*, **20**, 1 (1944).
[9] Petrov, N. N., Krotkina, N. A., Vadova, A. V., and Postnikova, Z. A., "Dynamics of the Origin and Development of Malignant Growths in Experiments on Monkeys" (Russian) (U.S.S.R. Acad. Med. Sci. Press, Moscow, 1952).
[10] Heller, M., "Histopathology of Irradiation", Ed. Bloom, W. (McGraw-Hill, New York, 1946).
[11] Brues, A. M., Lisco, H., and Finkel, M., "Carcinogenic Action of Some Substances which may be a Problem in Certain Future Industries", Rep., U.S. Atomic Energy Commission (1946).
[12] Koletsky, S., Bonte, F. J., and Friedell, H. L., *Cancer Res.*, **10**, 129 (1950).
[13] Owen, M., Sissons, H. A., and Vaughan, J., *Brit. J. Cancer*, **11**, 229 (1957).
[14] Downie, E. D., Macpherson, S., Ramsden, E. N., Sissons, H. A., and Vaughan, J., *Brit. J. Cancer*, **13**, 408 (1959).
[15] Anderson, W. A. D., Zander, G. E., and Kuzma, J. F., *Arch. Path.*, **62**, 262 (1956).
[16] Cherkasskii, L. A., *Vop. Onkol.* (Russian), **2**, 275 (1956).
[17] Litvinov, N. N., *Bjull. eksp. Biol. Med.* (Russian), **8**, 62 (1956); *Vop. Onkol.* (Russian), **2**, 285 (1956).
[18] Kuzma, J. F., and Zander, G. E., *Arch. Path.*, **63**, 198 (1957).
[19] Skoryna, S. C., and Kahn, D. S., *Cancer*, **12**, 306 (1959).
[20] Holgate, W., *J. Dent. Surg.* (in the press).
[21] Finkel, M. P., Biskis, B. O., and Scribner, C. M., Proc. 2nd Intern. Conf. Peaceful Uses Atomic Energy, Geneva (1958).

Incorporation of Tritiated Uridine into Amphibian Eggs

The incorporation of labelled precursors into amphibian embryos is limited by the presence of a coat which covers the embryo and which renders the embryo impermeable to a large number of substances. One of them is uridine. However, we found that embryonic cells the coat of which has been disintegrated by placing them in a medium totally devoided of calcium incorporate tritiated uridine very rapidly, while the control embryos do not. Using this procedure, we have been able to follow the incorporation of this substance into dissociated embryonic cells at different stages of development.

Eggs removed at the desired stages were decapsulated. These eggs, still in their vitelline membrane, were cultivated in the following medium: sodium chloride (17 per cent), 20 ml.; potassium chloride (0·5 per cent), 10 ml.; *tris*, 560 mgm.; water, 966 ml.; *N* hydrochloric acid, 4 ml.; citrate, 5 gm.

In this medium, the embryos disaggregate into a mass of dissociated cells surrounded by the vitelline membrane.

After dissociation, the cells were replaced in the same medium without calcium, but deprived of citrate. The incorporation of uridine was followed by the autoradiographic technique of A. Ficq[1], after fixation by freeze-substitution.

At the blastula and young gastrula stages, the incorporation of tritiated uridine is exclusively nuclear. Treatment of the sections with deoxyribonuclease before application of the photographic emulsion completely removes the radioactivity: on the other hand, treatment of the sections with water or ribonuclease has no effect on the radioactivity. Therefore, uridine seems to be incorporated into deoxyribonucleic acid. This incorporation probably occurs at the level of the pyrimidine bases of deoxyribonucleic acid, because hydrolysis of the sections with *N* hydrochloric acid for 5 min. at 60° has no effect on the radioactivity. During gastrulation and neurulation, nuclear activity remains intense. A greater heterogeneity in the distribution of radioactivity among the embryonic nuclei is observed. At the same time, radioactivity becomes conspicuous in the cytoplasm. Cytochemical tests indicate a change in the nature of the substances incorporating uridine. The nuclei, in slides treated with ribonuclease or *N* hydrochloric acid at 60°, now lose about half their radioactivity. After incubation of the sections in the presence of deoxyribonuclease, 30–40 per cent of the radioactivity remains in the nuclei. It should be mentioned that all the cells do not behave in exactly the same manner when they are submitted to this treatment. At the onset of segmentation of the egg, the importance of the coat is still such that penetration of the precursor is impossible even in the presence of citrate. Unsegmented eggs incubated in the presence of uridine and citrate for about 20 hr. exhibit nuclear incorporation in the daughter cells. At this stage, the localization of the tracks is either nuclear or chromosomal.

In summary, until the neurula stage, nuclear incorporation predominates over cytoplasmic incorporation. Uridine incorporation occurs principally into deoxyribonucleic acid during segmentation. After gastrulation, there is an incorporation of uridine into ribonucleic acid (both nuclear and cytoplasmic) as well.

N. Bieliavsky
R. Tencer

Laboratoire de Morphologie animale,
Faculté des Sciences,
Université libre de Bruxelles.

[1] Ficq, A., *Arch. Biol.*, **66**, 508 (1955).

BIOLOGY

Birefringence of Enamel Organic Matrix

To date little attention has been given to the appearances of the enamel organic matrix when examined between crossed nicols, and the few published observations show considerable disagreement. Cape and Kitchin[1], and Poole[2] reported that the enamel organic matrix is without intrinsic birefringence. Keil[3] and Schmidt[4] reported a weak positive intrinsic birefringence—the sign being described with respect to the long axis of the enamel prisms. Rushton[5] stated that this positive birefringence is strong, in fact stronger than the negative intrinsic birefringence of the mineral matter present in the mature tissue.

During current studies on the optical properties of dog enamel, results were obtained which support the views of Keil and Schmidt. In these studies ground sections, approximately 300μ in thickness, prepared from the developing maxillary permanent incisors of a two months old dog were demineralized in a formic and citric acid mixture. The demineralized sections were first imbibed for periods of 24 hr. in each fluid of a series prepared by mixing varying proportions of cedarwood oil (n_D=1·505) and monobromnaphthalene (n_D=1·659), and then examined between crossed nicols in monochromatic light —a sodium lamp being used as light source. The refractive indices of the imbibition fluids, determined with an Abbe refractometer, ranged from 1·505 to 1·598 by intervals of approximately 0·01. The retardation at selected points on the specimens was measured in each fluid by means of a Berek compensator.

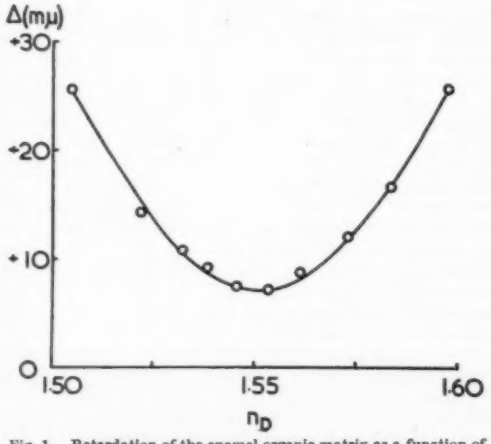


Fig. 1. Retardation of the enamel organic matrix as a function of the refractive index of the imbibition fluid

The type of imbibition curves thus obtained (Fig. 1) clearly indicates that in demineralized developing dog enamel organic matrix there is an interaction between positive form birefringence and positive intrinsic birefringence. Allowing for possible variations in prism direction giving rise to a crossed lamellar system[6], the strength of the positive intrinsic birefringence appears to be not less than 0·00002. Further, the refractive index of the organic matrix at this stage of development is shown by the imbibition curves to be about 1·55—a value confirmed by Becke line tests.

Thanks are due to Prof. L. R. Moore for making available the facilities to conduct this study in the Geology Department.

J. H. Allan

Oral Pathology Department,
The University,
Sheffield, 10.
Oct. 5.

[1] Cape, A. T., and Kitchin, P. C., *J. Amer. Dent. Ass.*, **17**, 193 (1930).
[2] Poole, D. F. G., *Quart J. Micro. Sci.*, **98**, 349 (1957).
[3] Keil, A., *Z. Zellforsch.*, **22**, 633 (1935).
[4] Schmidt, W. J., *Z. Zellforsch.*, **49**, 319 (1959).
[5] Rushton, M. A., *Brit. Dent. J.*, **67**, 1 (1939).
[6] Frey-Wyssling, A., "Submicroscopic Morphology of Protoplasm and its Derivatives" (Elsevier, Amsterdam, 1948).

Placental Grafts in Rats

During studies of experimental infection of the rat placenta attempts were made to transplant placental tissue from the uterus to the mother's omentum. Grafts of the allanto-chorion were not successful; but the yolk sac membrane, when transplanted at 15 days pregnancy, grew in a most remarkable manner.

After a number of pilot experiments the following technique was adopted. The abdominal cavities of rats (Albino Wistar strain) at 15 days pregnancy were opened under open ether anæsthesia. The uterus with its contained conceptuses was removed, but the ovaries left intact. A portion of yolk sac was carefully dissected from a placenta and returned to the mother's peritoneal cavity where it was wrapped in the omentum. The abdominal wound was then closed.

Of 12 rats treated in this manner all except one showed evidence of transplant growth at autopsy 4, 8 or 12 weeks later. Seven transplants grew into large mucus-containing cysts, the largest being more than 2 in. in diameter (Fig. 1). On histological examination a variety of tissues were frequently found together in the same graft. These included epidermoid cysts containing keratin and hair, hair follicles, sebaceous and sweat glands, mucus-secreting epithelium, whorled masses of mesenchyme connective tissue, smooth and striated muscle, cartilage and bone. The mucus-secreting epithelium was usually organized with other tissues so as to resemble gut wall, in that there were villi and surrounding layers of smooth muscle (Fig. 2).

The possibility of dependence of these grafts on hormones has been briefly investigated; removal of the

Fig. 1. Rat yolk sac graft to omentum, 12 weeks after transplantation. It has grown to more than 2 in. in diameter and contains large quantities of mucus

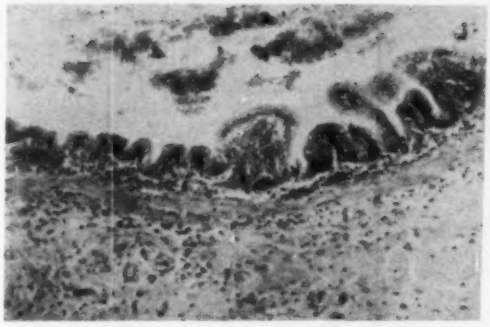


Fig. 2. As for Fig. 1. The wall of the graft is lined by mucus-secreting epithelium beneath which is connective tissue and layers of smooth muscle cells. Hæmatoxylin and eosin. (×150)

ovaries did not prevent successful transplantation, but the grafts did not grow to the same extent. Similar results occurred with homografts into 4 non-pregnant intact females. Homografts to 4 males grew in only 2 animals, where they produced just small quantities of mesenchyme connective tissue and tiny epidermoid cysts.

The variety of tissues produced in these grafts suggests that after transplantation to an unfamiliar site the endoderm and mesoderm cells of the rat yolk sac are capable of diverse differentiation.

As we have not found any previous account of similar transplants of placental tissue in rats we wish to place these initial results on record. Details and further experiments now in progress will be reported elsewhere.

J. M. Payne

Agricultural Research Council Field Station,
Compton, Near Newbury, Berks.

Sylvia Payne

Compton, Near Newbury,
Berks.
Oct. 29.

In vitro Culture of *Musa balbisiana* Colla Embryos

The culture of excised embryos has been reported for many plants[1], but, to our knowledge, there are no reports concerning the successful cultivation of embryos of seeded bananas. In the course of investigations on the rhizosphere of bananas, it became necessary to obtain plants of *Musa balbisiana* Colla, the roots of which were free of micro-organisms. The germination of intact seeds of this variety under sterile conditions was generally unsuccessful; hence, the possibility of obtaining sterile plants from excised embryos was investigated.

Preliminary studies were conducted with a modified Knudson's[2] medium, containing 2 per cent sucrose and 1·2 per cent agar. Intact seeds were surface sterilized in filtered $CaOCl_2$ (10 gm. $CaOCl_2$ in 150 ml. of distilled water)[3] *in vacuo* for 45 min. The embryos were removed aseptically and placed on 30 ml. of medium in 4 oz. wide-mouth screw-cap jars. Enlargement of the embryos was followed by leaf and root development. The roots, however, failed to penetrate the medium, and growth of the plantlets ceased after approximately 6 weeks, resulting ultimately in death of the plants. When young plantlets were transferred from the Knudson medium to that of Randolph and Cox[3], which contained only 0·7 per cent agar, root development improved and the roots penetrated into the medium.

In all current studies the Randolph and Cox medium is being used. The agar content of the medium has been further reduced to 0·5 per cent, since more rapid growth and healthier plants have been obtained with this concentration. Sucrose was found to be better than glucose or fructose as a carbohydrate source and 4 per cent was the optimum level. Intact seeds are surface sterilized by agitating for 30–35 min. in $CaOCl_2$ on a wrist-action shaker; the use of vacuum was found to be unnecessary in order to obtain sterility. The seeds are split longitudinally and the embryos aseptically removed. Excised embryos may be immersed in $CaOCl_2$ for up to 5 min. without deleterious effects, in agreement with Tukey's[4] experience with the embryos of stone fruits. In early experiments, the embryo, after enlargement, was re-oriented on the agar so that the cotyledon was placed in contact with the medium to provide a larger surface area for absorption. Repositioning was unnecessary when the low agar medium was used, since the weight of the embryo embedded the cotyledon into the soft agar.

Callus-like growth generally is evident 5–6 days after excision, followed by the appearance of the coleoptile and roots. Often, delicate hair-like growths arise from the surface of germinating embryos prior to the appearance of the coleoptile and roots. Two weeks after excision, the first leaf and roots have developed. A six-week old plantlet is illustrated in Fig. 1.

Fig. 1. *Musa balbisiana* Colla. Six-week-old plantlet developed in embryo culture

Plants developed from mature embryos, excised from seeds which were stored for periods of 3 weeks to 1½ years after harvest, were grown aseptically in the original culture vessels for 3 months. They were then transplanted to growth tubes wherein the roots have been maintained under sterile conditions for an additional 3 months. These plants are approximately 8 in. tall and have 8–10 fully developed leaves and well-developed root systems. The plants are smaller than seedlings of the same age which developed in soil under greenhouse conditions from intact seeds, but otherwise they appear to be similar in all respects.

The application of embryo culture to studies in plant breeding and nutrition have been pointed out by Crocker and Barton[1]. Our experiments have demonstrated that a wild relative of the commercial banana can be grown successfully from mature embryos and that the technique could possibly be applied to other varieties of bananas.

Studies are in progress on the nutrition, physiology, and morphology of *M. balbisiana* plants derived from embryos, results of which will be presented elsewhere.

Elsie A. Cox
G. Stotzky
Roger D. Goos

Central Research Laboratories,
United Fruit Co.,
Norwood, Massachusetts.

[1] Crocker, W., and Barton, Lela V., "Physiology of Seeds" (Chronica Botanica Co., Waltham, Mass., 1953).
[2] Knudson, L., *Amer. J. Bot.*, **37**, 241 (1950).
[3] Randolph, L. F., and Cox, L. G., *Proc. Amer. Soc. Hort. Sci.*, **43**, 283 (1943).
[4] Tukey, H. B., *Bot. Gaz.*, **99**, 630 (1938).

SOIL SCIENCE

Weathering of Fly Ash

A considerable body of information is now available regarding the minerals present in fresh fly ash which are available to plants[1,2]. During combustion of the coal, adventitious clay minerals such as kaolinite are broken down, and a material is produced containing all the mineral constituents of coal, but with a very low cation exchange capacity (3 m.equiv. per 100 gm.). Many metal oxides are embedded in the glassy phase of the fly ash and may be released slowly over a period of time. In considering the possibilities of establishing crops or plant cover on fly ash deposits, it seemed worth while, therefore, to obtain information on the rate of change of selected constituents. Of particular interest were the elements, for example, boron and aluminium, that are present in quantities likely to be injurious to plants. In the studies to be briefly described here determinations were also made of phosphorus, potassium, calcium and iron in order to obtain any information regarding any likely change in fertilizer requirements as the age of the ash increases.

Ash tip areas covering an age-range of 0–25 years were available at Hams Hall power station and analyses have been made of samples collected from them. Phosphorus, iron and aluminium were determined in extracts obtained using Morgan's reagent. Boron, potassium and calcium were determined in water extracts using standard time procedure as for water-soluble soil constituents. These results, plotted against the age of the ash tip, are shown in Figs. 1 and 2 and indicate a rapid initial decrease in available concentration.

In order to see how far the changes could be due simply to leaching, columns 5 cm. in diameter and containing 25 gm. of fresh ash were set up and leached under a constant head of about 1–5 cm. of water and at a rate of about 1 ml./min. The leachate was collected in aliquots of 40 ml. for analysis. The curves obtained for potassium, calcium and boron (Fig. 3) are in agreement with field observations: a rapid initial decrease followed by a steady release of the elements. No phosphate, aluminium or iron was detected in the leachate. It was also noted that in the weathering of field samples the decrease in

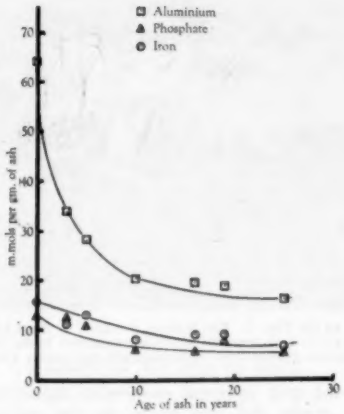


Fig. 1. Amounts of aluminium, iron and phosphate in Morgan's extract of P.F. ash of varying age

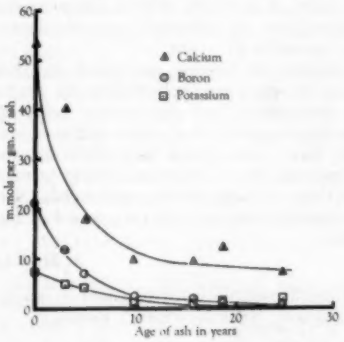


Fig. 2. Amounts of calcium, boron and potassium in water extract of P.F. ash of varying age

available iron was molecularly equivalent to the fall in available phosphate and that the fall in available calcium was similarly equivalent to the fall in available aluminium. These facts and the laboratory leaching curves suggest that, for these elements, the decrease in available concentration might be due to chemical fixation rather than to leaching out.

The equivalence of the change in available calcium and aluminium would suggest the formation of a dicalcium aluminate but there is as yet no evidence for this. X-ray studies[3] indicate the formation of a tetra calcium aluminate and some calcium sulpho-aluminate after prolonged hydration and it seems likely that some interaction between calcium and aluminium takes place. The rapid loss of soluble calcium found in the leaching experiments would not be likely to occur to the same extent under field conditions as the relatively soluble calcium hydroxide would be rapidly carbonated and fixed in an insoluble form.

The fall in available concentration of elements injurious to plant growth on the fly ash, namely boron and aluminium, is also of particular interest. It may be seen from Figs. 1 and 2 that these elements fall rapidly from a high injurious level to a level approaching that of a normal soil (for example, 1 p.p.m. water-soluble boron[4]). Fig. 4 shows how the boron content of wild white clover grown on ash falls with increasing age of the ash used. It may be concluded that although the range of possible crops

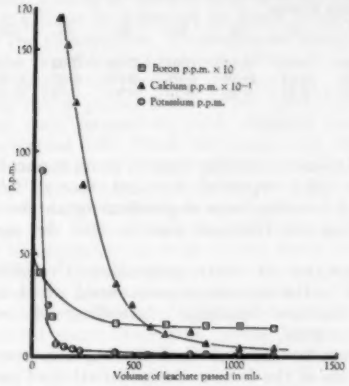


Fig. 3. Laboratory leaching curves

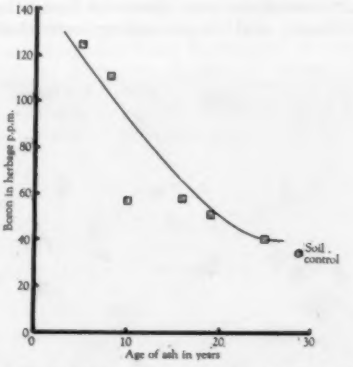


Fig. 4. Boron in plant tissue grown upon ash of varying age

is limited during the first few years of the life of a fly ash tip a considerably wider range of crops may be used as the ash weathers.

In using already existing ash tips of different ages for the investigation of weathering it has been assumed that (*a*) the coal source and composition had remained reasonably constant over the 25-year period and (*b*) that improved methods of coal grinding, resulting in the production of a finer ash, have not significantly altered the availability of elements as for example by increasing surface area. The latter possibility cannot be ignored but the agreement between the column leaching experiments and the field observations indicates that a true picture of weathering under field conditions has been obtained. The samples examined were procured from areas with free drainage and no evidence of waterlogging. The rate of decrease in soluble constituents in areas with a high water table and/or impeded drainage may well be considerably lower.

L. H. Jones
A. V. Lewis

Botany Department,
The University,
Birmingham, 15.
Aug. 27.

[1] Rees, W. J., and Sidrak, G. H., *Plant and Soil*, **8**, 141 (1956).
[2] Holliday, R., *et al.*, *Nature*, **181**, 1079 (1958).
[3] Private communication from Central Electricity Generating Board Research Laboratories, Leatherhead.
[4] Bear, F. E. (Ed.), "Chemistry of the Soil", 329 (Reinhold Publishing Co., New York, 1955).

PATHOLOGY

Periosteal Osteoclasts, Skeletal Development and Ageing

As far back as 1873, Kölliker[1] observed the existence of osteoclasts in the periosteum of normal bone. Lacroix[2] also made several references to the presence of periosteal osteoclasts during development of the perichondral collar of long bones. Quantitative information, however, is not available concerning the size of the population of periosteal osteoclasts and the appearance, disappearance, and stability of the population during ageing. The importance of the presence of these cells at periosteal sites has been largely neglected. Environmental conditions which are found in the periosteum make for an excellent study of osteoclastic origin, function, fate and biochemical nature.

Jackson[3] and Jordan[4] have reported mitosis in the nuclei of osteoclasts. Amitosis has also been noted by Kolliker[5]; however, these events are extremely rare, and cannot account for the rapid appearance and disappearance of large numbers of osteoclasts. Kölliker maintained that osteoclasts originated from the fusion of osteoblasts. More recently Heller *et al.*[6] described the formation of osteoclasts from osteoblasts or osteocytes under the influence of toxic doses of parathormone.

Because of the nature of the periosteum, it was felt that a study of periosteal osteoclasts may reveal information concerning the origin and fate of osteoclasts under normal conditions, which could not be readily observed in the more complex environment of the metaphysis. For a better comprehension of bone development and ageing, population studies were made from the left femora of 45 female mice of the Brookhaven National Laboratory strain of Swiss Albino. The right femur of each mouse was fractured by digital pressure applied to the mid-shaft under ether anæsthesia. The femora were fractured at 1, 5, 8, 26, and 52 weeks of age, and the mice were killed 24 hr., 1 week, and 2 weeks post-fracture. One hour before they were killed, they received a subcutaneous injection of tritium-labelled thymidine in sterile aqueous solution (0·5 μc./gm. body-weight). Stripping film autoradiographs were prepared from paraffin sections of whole decalcified femora. Additional sections were stained routinely with hæmatoxylin and eosin.

The tritium-labelled thymidine technique and interpretation of data are based on the successful studies employed by Hughes *et al.*[7], Cronkite *et al.*[8,9], Bond *et al.*[10], and Quastler and Sherman[11].

The total population of periosteal osteoclasts was found to be much larger in animals the femora of which were undergoing active bone development and remodelling than in older mice. Counts made of the population of periosteal osteoclasts of young mice revealed extensive fluctuations within very short periods of time (Table 1 and Fig. 1). A more stable population was exhibited by older animals, the total osteoclastic population of which was much lower than the younger mice. Considerable differences were found between counts made from the anterior and posterior aspects of the femur. A shift in the position of the major population of osteoclasts was observed at least 3 times during the ages studied. This shift is indicated in Fig. 1 at the points of intersection.

It is interesting to point out that on numerous occasions in animals of different ages cells were

Table 1. Average Number of Osteoclasts Per Unit Distance* of Periosteum Covered at the Distal Epiphyseal Aspect of Mouse Femur

Age (weeks)	1	2	3	5	6	7	8	9	10	26	27	28	52	53	54
Anterior + posterior counts	0·08	0·35	0·51	0·69	0·26	0·98	0·46	0·30	0·34	0·18	0·07	0·10	0·02	0·02	0·02
Anterior counts	0·13	0·54	0·61	0·55	0·12	0·67	0·24	0·11	0·47	0·06	0·01	0·10	0·01	0·01	0·01
Posterior counts	0·04	0·29	0·41	0·79	0·40	1·30	0·70	0·47	0·21	0·30	0·13	0·10	0·02	0·04	0·06

* An average of 173 unit distances covered per age group.

observed having a size comparable to osteoblasts. Except for the presence of a single nucleus, the cells answered to the description of osteoclasts in all cytological respects. The mononucleated state was verified from serial sections. These mononucleated cells, which in many instances resided in well-formed Howship's lacunæ, exhibited an eosinophilic, foamy cytoplasm, lacking in the presence of a juxtanuclear vacuole. A juxtanuclear vacuole is seen in active osteoblasts. Cells of this description were never encountered in the metaphyses. Ch'uan[12] has observed mononucleated osteoclasts in the jaws of a two-day-old hamster and the stripped periosteum of a newly born goat.

Several foci of osteoblasts arranged in tight clusters were observed at ages where active periosteal osteoclast formation was taking place. Individual cells making up these clusters finally lost the identity of their cytoplasmic borders, cytoplasmic basophilia, and juxtanuclear vacuoles. The usual population of periosteal osteoblasts was reduced in the immediate areas where osteoclasts were being formed.

Autoradiographs of intact femora revealed an essentially weakly labelled periosteum. The highest labelling occurred at the perichondral region. Osteogenic cells of the osteogenic layer of the periosteum near the fibrogenic layer were labelled most frequently. Osteoblasts, however, were rarely seen labelled. Osteoclasts, on the other hand, were never seen labelled above background (Fig. 2). This is also true of metaphyseal osteoclasts. With increasing age labelling of periosteal cells became more infrequent.

Within 24 hr. after fracture and at all ages studied, the periosteum became increasingly labelled about the fracture site. In older animals, however, the overall labelling was not as high as the level found in younger mice. Periosteal labelling continued to increase until the osteogenic cells of the fracture callus differentiated into cartilage cells (Fig. 3). Diminished periosteal labelling was noted when the active replacement of the cartilagenous callus by endochondral ossification took place. With increasing age there was a retardation of fracture healing in mice. Reduction in the rate of bone repair has been observed and reported for rat femora[13,14]. The degree of labelling was dependent upon the stage of repair that the fracture was in, and the age of the animal.

No uptake of tritium-labelled thymidine was observed in the numerous osteoclasts which appeared during fracture healing. Labelling of osteocytes was never seen.

The results showed that during the remodelling of the ends of the femur, the population of osteoclasts present in the periosteum fluctuated radically within short periods of time. Since active formation of periosteal osteoclasts was observed from the fusion of osteoblasts, and degenerating osteoclasts were

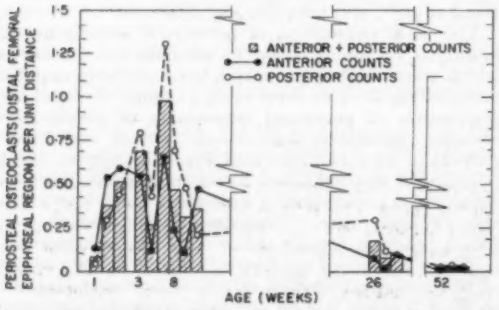


Fig. 1. Graph showing a comparison between the size of the osteoclastic population of the anterior and posterior aspects of the periosteum in the distal end of the femur at different ages

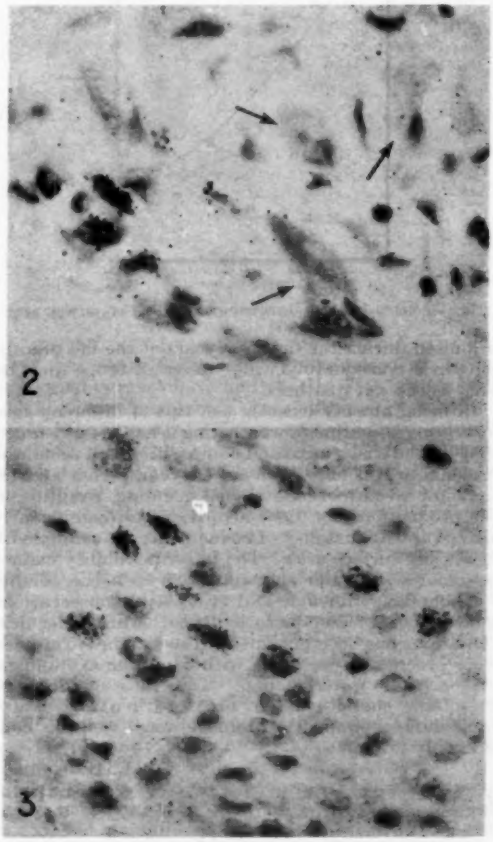


Fig. 2. Photomicrograph revealing tritium-labelled thymidine marking of osteoblasts during active fracture healing in a 2-week-old-mouse the femur of which had been fractured 1 week prior. Arrows point to non-labelled osteoclasts (×c. 534 oil)

Fig. 3. Photomicrograph revealing tritium-labelled thymidine marking of osteogenic cells of the periosteum active in the production of the fracture callus. The cells are undergoing transformation into chondrogenic cells in a 2-week-old mouse the femur of which had been fractured 1 week prior (× c. 560 oil)

not readily found, a reduction in population within one week's time is believed to have occurred as a result of the dissociation of osteoclasts into precursor cells. It is possible that the population of osteoclasts migrated from one position to another. Had this migration taken place, there would have been fewer periosteal cells present in such regions, unless the other periosteal cells filled the gap. No deficiency was encountered in the population of periosteal osteoblasts or osteogenic cells at that time. At a point, however, when the total (anterior and posterior) population of osteoclasts diminished rapidly, the presence of degenerating cells should have been seen. Nevertheless, degenerating osteoclasts were not encountered. Autoradiographic results indicated that there was no uptake of tritium-labelled thymidine by periosteal osteoclasts and hence there occurred neither deoxyribonucleic acid synthesis nor reproduction by mitotic division.

The observations indicate that periosteal osteoclasts derive their origin from osteoblasts and their fate is to dissociate into precursor cells. It appears that with increasing age beyond the period of active bone remodelling, there is a decrease in the population of osteoclasts; however, changes in age in individual osteoclasts were not seen.

I wish to acknowledge the suggestions of Dr. E. P. Cronkite, and the technical assistance of Miss M. Pavelec.

E. A. Tonna

Division of Experimental Pathology,
Medical Research Center,
Brookhaven National Laboratory,
Upton, New York.
Oct. 26.

[1] Kölliker, A., "Die normale Resorption des Knochengewebes und ihre Bedeutung für die Entstehung der typischen Knochenformen" (Vogel, Leipzig, 1873).
[2] Lacroix, P., "The Organization of Bones" (The Blakiston Co., Philadelphia, 1951).
[3] Jackson, C. M., *Archiv Anatomie u. Entwicklungsgeschichte*, **33**, 70 (1904).
[4] Jordan, H. E., *Anat. Rec.*, **30**, 107 (1925).
[5] Kölliker, A., "Handbuch der Gewebelehre des Menschen", 6th Ed., 1 (W. Engelman, Leipzig, 1889).
[6] Heller, M., McLean, F. C., and Bloom, W., *Amer. J. Anat.*, **87**, 315 (1950).
[7] Hughes, W. L., Bond, V. P., Brecher, G., Cronkite, E. P., Painter, R. B., Quastler, H., and Sherman, F. G., *Proc. U.S. Nat. Acad. Sci.*, **44**, 476 (1958).
[8] Cronkite, E. P., Fliedner, T. M., Bond, V. P., Rubini, J. R., Brecher, G., and Quastler, H., *Ann. N.Y. Acad. Sci.*, **77**, 803 (1959).
[9] Cronkite, E. P., Fliedner, T. M., Bond, V. P., and Robertson, J. S., in "The Kinetics of Cellular Proliferation", F. Stohlman, editor (Grune and Stratton, Inc., New York, 1959).
[10] Bond, V. P., Fliedner, T. M., Cronkite, E. P., Rubini, J. R., and Robertson, J. S., *ibid.*
[11] Quastler, H., and Sherman, F. G., *Exp. Cell Res.*, **17**, 420 (1959).
[12] Ch'uan, C. H., *Anat. Rec.*, **49**, 397 (1931).
[13] Tonna, E. A., *Nature*, **181**, 486 (1958).
[14] Tonna, E. A., *J. Gerontol.*, **14**, 159 (1959).

ARCHÆOLOGY

An Alternative Interpretation of the Supposed Giant Deciduous Hominid Tooth from Olduvai

Dr. L. S. B. Leakey has reported[1,2] the discovery at Olduvai of what he regards as a large second lower deciduous molar of a hominid exhibiting affinities with *Sinanthropus* and the Heidelberg jaw, but not with australopithecines. Associated with it was a worn deciduous canine. The purpose of this communication is to show that the molar is, in fact, a permanent upper tooth, probably of an australopithecine.

The molar appears to be a somewhat aberrant specimen, since the morphologically less-stable areas —anterior and posterior foveæ and either the lingual or buccal faces, depending on whether the tooth is maxillary or mandibular—have many accessory cusps.

Assuming the tooth to be mandibular, as Leakey does, and ignoring the accessory cusps for the present, it is not possible to fit the main cusp or fissure patterns into either of the two common types for hominoid mandibular molars: the five- or four-cusped types. The relationship of the cusps to each other is wrong: the buccal cusps are too far back relative to the lingual ones. Furthermore—a major difficulty in interpreting the tooth as mandibular—the anterior buccal cusp ('protoconid') and the distal lingual cusp ('entoconid') are linked by an almost cusp-high crest. This divides the fissure system into two quite separate parts, while even in very worn mandibular molars of earlier hominids the fissure system separates these two cusps deeply and is not divided into two portions. Also, this oblique, high crest with a deep fissure posterior to it cutting deeply between the 'protoconid' and 'hypoconid', distinctly sets off an almost symmetrical anterior triangle of major cusps from a single, semi-isolated major cusp posteriorly. This is a feature not found on mandibular molars.

On the other hand, the high, oblique crest in this position on the crown, the anterior trigon of three major cusps and a postero-medial semi-isolated cusp (hypocone) are not merely common on maxillary molars but also are regarded as being the standard pattern for them. Leakey regards two large accessory cusps in the posterior fovea as very unlikely on a maxillary tooth. Fig. 1 (*C*) illustrates an almost identical condition in an upper molar; one *Australopithecus* upper molar from Sterkfontein has no less than five accessory cusps in this position.

The crown morphology is thus clearly in favour of this tooth being maxillary. The disposition of the roots provides an absolute check, since early hominid deciduous or permanent mandibular molars have two roots, an anterior and a posterior, while maxillary ones have a single lingual and two buccal roots. There can thus be no confusion. Although damaged, the Olduvai specimen clearly has two buccal roots and a larger, single lingual one. For comparison a maxillary permanent australopithecine molar in a similar state of preservation is shown in Fig. 1 (*D*) along with the entirely different condition in an australopithecine deciduous lower second molar (Fig. 1, *F*). The roots of the Olduvai specimen manifestly could not belong to a mandibular tooth.

Leakey regards the tooth as deciduous because of: (i) divergent roots, (ii) constriction of the neck, (iii) nature of the roots, and (iv) association with a lower deciduous canine.

Divergent roots and a constricted neck, in earlier hominid molars, do not necessarily indicate deciduous teeth, since the permanent teeth commonly have both features well developed. This is well shown by the extensive collections of australopithecine teeth now known. As already indicated in the case of (iii), the nature of the roots is more consistent with the specimen being a permanent upper tooth. Finally, (iv) is a broken reed. If this tooth is regarded as a second lower deciduous molar, then it is highly

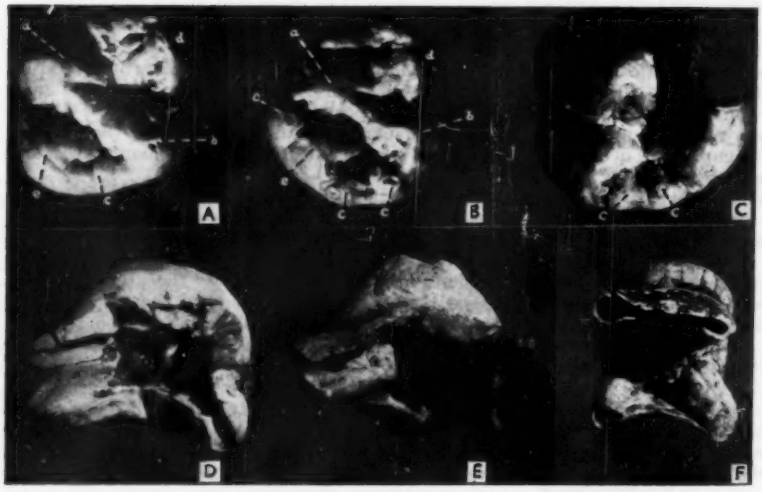


Fig. 1. (*A*) and (*C*) Occlusal views of australopithecine maxillary molars. (*B*) Occlusal view of Olduvai molar. View of the root system (damaged) of an australopithecine maxillary molar (*D*) and of the Olduvai molar (*E*). (*F*) View of root system of an australopithecine deciduous mandibular molar. In all cases the lingual side is to the left. In the upper row the anterior end is at the top and in the lower row at the bottom. In (*A*) and (*B*) the high oblique crest links *a* and *b*; the trigon is formed by *a*, *b* and *d*. *a*, Protocone; *b*, metacone; *c*, accessory cusps; *d*, paracone; *e*, hypocone

unlikely that it belonged to the same individual as the deciduous canine. The latter is well worn, and had already lost about half the crown height. At this stage, dm_2 of the individual would already have been appreciably worn, not virtually unworn as is the Olduvai molar. Furthermore, at that stage permanent molars with fully formed crowns would also have been present. On the other hand, while the deciduous canine is only very slightly larger than the observed range of the very small collection of australopithecine equivalents, the molar is appreciably larger than the largest australopithecine dm_2 known, but is well within the observed range for permanent molars.

I believe, therefore, that the Olduvai molar is neither deciduous nor mandibular, but is a permanent upper tooth, probably australopithecine.

J. T. Robinson

Transvaal Museum,
Pretoria.

[1] Leakey, L. S. B., *Nature*, **181**, 1099 (1958).
[2] Leak y, L. S. B., *Illus. Lond. News*, **232**, 1104 (1958).

In my original paper I was at pains to point out that of a number of dental surgeons and anatomists to whom I had then showed this tooth, no two were agreed upon what its place was in the dental series. Since that time I have had many other views put to me in letters and also verbally. Clearly, the tooth is so aberrant there is little hope of agreement.

It seems to me to be immaterial, at the moment, as to which opinion is correct. What is certain and important is that it is: (*a*) a very large *hominid* molar; (*b*) that it was found within a few inches of a small deciduous canine tooth and within a few minutes; (*c*) that it comes from the base of Bed II, Olduvai, associated with Stage I of the Chellean culture, and was found on a living floor; (*d*) that the relative size of the molar to the canine is comparable to that seen in *Zinjanthropus*, and to a lesser extent in *Paranthropus* and *Australopithecus*.

I still retain my opinion that, in spite of its unusual form, it is a lower deciduous molar, and the fact that I have now three modern hominid lower deciduous molars (taken from mandibles) that similarly have three roots and not two, and set in just this manner, shows that Robinson's reliance on the number of roots, to clinch his argument, is not realistic. Similarly, while I agree (and also stressed in my original paper) that if the tooth is, as I believe, a lower molar, it does *not* show either of the two common types of cusp patterns, the cusp pattern which it does exhibit is, nevertheless, one which does occur in Hominids, both recent and extinct, as I showed before.

Since that article was written, I have found that the same pattern occurs in many other modern mandibular molars, and we must indeed now regard it as a third fairly common pattern, since I found it in 15 per cent of a random sample of mandibles.

Among the many anatomists who have now seen the fossil tooth in question, there are some who agree wholly with me; there are others who agree with Robinson, and there are yet others whose views do not agree with either of us. Everything depends upon what weight one gives to the number and disposition of the roots, as compared with the disposition of the cusps and their interpretation.

It appears that Robinson, from his study of the cast, is clearly not aware that what he refers to as "the ridge" linking the two cusps is divided by a very clear fissure, and is not a continuous ridge at all. This fissure shows very clearly in the photograph which I published and which was taken of the original tooth, but does not show in the photograph used by Robinson, which is apparently taken of a cast.

Finally, let me say that since the molar teeth of *Zinjanthropus* exceed the molar teeth of *Australopithecus* or *Paranthropus* in size, it is not unlikely that the deciduous molars of a descendant of *Zinjanthropus* should also be much larger than the deciduous molars of the known South African Australopithecinae, and since Chellean Stage I is a direct derivative of the Oldowan culture, it is reasonable to expect that the makers of Chellean Stage I will prove to be more advanced descendants of *Zinjanthropus*; heading in the *Homo* direction.

L. S. B. Leakey

Coryndon Museum,
Nairobi,
Kenya.

FORTHCOMING EVENTS

*(Meetings marked with an asterisk * are open to the public)*

Monday, February 8

BRITISH SOCIETY FOR THE PHILOSOPHY OF SCIENCE (in the Joint Staff Common Room, University College, Gower Street, London, W.C.1), at 5.30 p.m.—Prof. R. L. Goodstein: "The Significance of Incompleteness Theorems".

INSTITUTION OF ELECTRICAL ENGINEERS, ELECTRONICS AND COMMUNICATIONS SECTION (at Savoy Place, London, W.C.2), at 5.30 p.m.—Discussion on "Present Views on Ground-Wave Propagation" opened by Mr. G. Millington.

UNIVERSITY OF LONDON (at Senate House, London, W.C.1), at 5.30 p.m.—Prof. A. T. Ippen (Massachusetts Institute of Technology): "Tide-dynamics in Estuaries".* (Further lectures on February 10 and 12.)

ROYAL INSTITUTE OF CHEMISTRY (joint meeting with the SIR JOHN CASS COLLEGE CHEMICAL SOCIETY, at the Sir John Cass College, Jewry Street, London, E.C.3), at 6.30 p.m.—Prof. E. D. Hughes, F.R.S.: "Reaction Mechanisms".

ROYAL GEOGRAPHICAL SOCIETY (at 1 Kensington Gore, London, S.W.7), at 8.30 p.m.—Mr. H. J. B. Harding: "The Channel Tunnel".

Tuesday, February 9

ZOOLOGICAL SOCIETY OF LONDON (at the Zoological Gardens, Regent's Park, London, N.W.1), at 5 p.m.—Scientific Papers.

TEXTILE INSTITUTE (at the Chemical Society, Burlington House, Piccadilly, London, W.1), at 6.30 p.m.—Mr. E. Roberts and Mr. F. P. Thompson: "Domestic Washing of Textiles".

ROYAL AERONAUTICAL SOCIETY (at 4 Hamilton Place, London, W.1), at 7 p.m.—Mr. E. C. Carter: "Model Testing in the Aircraft Research Association".

RADAR AND ELECTRONICS ASSOCIATION (at the Royal Society of Arts, John Adam Street, Adelphi, London, W.C.2), at 7.30 p.m.—Mr. E. Wolfendale: "Transistors—To-day and To-morrow".*

Wednesday, February 10

PHYSICAL SOCIETY, LOW TEMPERATURE GROUP (at the Royal School of Mines, Prince Consort Road, London, S.W.7), at 4 p.m.—Dr. H. M. Rosenberg: "Some Low Temperature Experiments on the Alkali Metals".

GEOLOGICAL SOCIETY OF LONDON (at Burlington House, Piccadilly, London, W.1), at 5 p.m.—Sir Edward Bailey and Dr. W. J. McCallien: "Some Aspects of the Steinmann Trinity—Mainly Chemical"; Dr. M. J. Fleuty: "The Three-Fold Systems in the Metamorphic Rocks of Upper Glen Orrin, Ross-shire and Inverness-shire" (to be read by Prof. J. Sutton).

INSTITUTION OF ELECTRICAL ENGINEERS, SUPPLY SECTION (at Savoy Place, London, W.C.2), at 5.30 p.m.—Dr. R. L. Grimsdale and Mr. P. H. Sinclare: "The Design of Housing-Estate Distribution Systems using a Digital Computer"; Mr. U. G. W. Knight: "The Logical Design of Electrical Networks using Linear Programming Methods".

SOCIETY OF CHEMICAL INDUSTRY, FOOD GROUP—NUTRITION PANEL (at 14 Belgrave Square, London, S.W.1), at 6.15 p.m.—Mrs. P. Fisher and Miss M. Corbridge: "The Public Attitude to Nutrition".

INSTITUTE OF METALS (at 17 Belgrave Square, London, S.W.1), at 6.30 p.m.—Dr. W. C. Winegard (University of Toronto): "Solidification of Alloys".

INSTITUTE OF WOOD SCIENCE (at Imperial College, Exhibition Road, London, S.W.7), at 6.45 p.m.—Mr. G. Garlick: "The Quality and Grading of Softwood in Relation to End Use".

BRITISH INTERPLANETARY SOCIETY (in the Hoare Memorial Hall, Church House, Great Smith Street, Westminster, London, S.W.1), at 7 p.m.—Prof. Alla Masevich: "Soviet Space Research".

SOCIETY FOR PSYCHICAL RESEARCH (at Kensington Town Hall, Kensington High Street, London, W.8), at 7 p.m.—Mr. G. Zorab: "Relationships in Spontaneous Paranormal Phenomena".

WOMEN'S ENGINEERING SOCIETY, LONDON BRANCH (at Hope House, 45 Great Peter Street, Westminster, London, S.W.1), at 7 p.m.—Prof. J. G. Ball: "Uses of New Metals".

ASSOCIATION OF CLINICAL BIOCHEMISTS, SOUTHERN REGION (in the Chemistry Lecture Theatre of the new Middlesex Hospital Medical School Building, Cleveland Street, London, W.1), at 7.30 p.m.—Dr. John B. Jepson: "Pitfalls in the Investigation of Metabolism through Urine Analysis; Some Cautionary Examples from Recent Studies of Phenylketonuria, Schizophrenia and Hartnup Disease".

Thursday, February 11

ROYAL SOCIETY (at Burlington House, Piccadilly, London, W.1), at 4.30 p.m.—Miss Elsie M. Widdowson and Prof. R. A. McCance, F.R.S.: "Some Effects of Accelerating Growth. I: General Somatic Development"; Mr. J. W. T. Dickerson and Miss Elsie M. Widdowson: "Some Effects of Accelerating Growth. II: Skeletal Development"; Mr. P. Hicken and Mr. P. L. Krohn: "The Histocompatability Requirements of Ovarian Grafts in Mice".

LINNEAN SOCIETY OF LONDON (at Burlington House, Piccadilly, London, W.1), at 5 p.m.—Prof. C. F. A. Pantin, F.R.S.: "Alfred Russel Wallace and his Pre-Darwinian Essay"; Mr. Quentin Bone: "The Origin of the Chordates", with a Discussion to be opened by Dr. G. S. Carter.

ANTIQUARIAN HOROLOGICAL SOCIETY (at the Science Museum, South Kensington, London, S.W.7), at 7 p.m.—Mr. B. Caillard: "Pendulum Watches".

SOCIETY OF INSTRUMENT TECHNOLOGY (at Manson House, 26 Portland Place, London, W.1), at 7 p.m.—Mr. T. A. Lucas: "Measurement, Automatic Control and Data Reduction as Applied to a Cyclic Plant".

CHEMICAL SOCIETY (in the Lecture Theatre, The Royal Institution, Albemarle Street, London, W.1), at 7.30 p.m.—Prof. P. L. Pauson: "Hydrocarbon-metal Carbonyls" (Tilden Lecture).

Friday, February 12

ASSOCIATION OF APPLIED BIOLOGISTS (at the Royal Entomological Society, 41 Queen's Gate, London, S.W.7), at 10.50 a.m.—Meeting on "Aspects of Crop Physiology".

BRITISH PSYCHOLOGICAL SOCIETY, OCCUPATIONAL PSYCHOLOGY SECTION (in the Department of Psychology, Birkbeck College, Malet Street, London, W.C.1), at 1 p.m.—Annual Meeting. Mr. D. E. Broadbent: "Industrial Inspection and Recent Advances in Psycho-Physics" (Chairman's Address).

UNIVERSITY OF LONDON (at Bedford College, Regent's Park, London, N.W.1), at 5.30 p.m.—Prof. E. Wegmann (Neuchâtel): "Some Aspects of the Geology of the Basements".*

ROYAL AERONAUTICAL SOCIETY (at 4 Hamilton Place, London, W.1), at 7 p.m.—Mr. N. D. Norman and Mr. T. Clutterbuck: "Choice of Aerial Vehicle".

ROYAL INSTITUTION (at 21 Albemarle Street, London, W.1), at 9 p.m.—Mr. F. T. Bacon: "Fuel Cells: Will They Soon Become Major Sources of Electrical Energy ?"

Saturday, February 13

BIOCHEMICAL SOCIETY (at the Royal College of Surgeons, Lincoln's Inn Fields, London, W.C.2), at 10 a.m.—Symposium on "The Biochemistry of Mucopolysaccharides".

APPOINTMENTS VACANT

APPLICATIONS are invited for the following appointments on or before the dates mentioned:

ASSISTANT (honours agricultural science graduate) IN CROP HUSBANDRY—The Secretary, Faculty of Agriculture, University College, Glasnevin, Dublin (February 12).

LECTURER IN THE DEPARTMENT OF MATHEMATICS—The Secretary, The University, Edinburgh (February 13).

SENIOR LECTURER OR LECTURER IN THE DEPARTMENT OF ELECTRICAL ENGINEERING (ELECTRONICS)—The Registrar, The University, Liverpool, quoting Ref. CV/N (February 13).

LECTURER OR SENIOR LECTURER IN BIOLOGY; and a LECTURER IN CHEMISTRY in the Training Department—The Warden, University of London Goldsmiths College, London, S.E.14 (February 15).

PLANT CYTOGENETICIST, Scientific Officer (with an honours degree in botany, and preferably postgraduate experience in cytological research) at the Royal Botanic Garden, Edinburgh, for the cytological exploration of the living collections in the Garden and the development of the cytogenetic contribution to problems of plant taxonomy—The Establishment Officer (B), Ministry of Works, 122 George Street, Edinburgh 2 (February 15).

SENIOR RESEARCH ASSISTANT (with a Ph.D. in theoretical physics or equivalent research qualifications, and preferably some experience in many body problems, or the methods of field theory) to Dr. N. H. March in the Department of Physics, for work concerned with electron correlation in metals—The Registrar, The University, Sheffield 10 (February 15).

ASSISTANT EXPERIMENTAL OFFICER or EXPERIMENTAL OFFICER (graduate) IN THE PLANT PATHOLOGY DEPARTMENT, for work on insect transmission of viruses—The Secretary, Rothamsted Experimental Station, Harpenden, Herts (February 20).

ASSISTANT IN BACTERIOLOGY (SCIENCE)—The Secretary of University Court, The University, Glasgow (February 20).

DEMONSTRATOR IN GEOGRAPHY at the University of New England, Australia—The Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1 (February 20).

LECTURER and an ASSISTANT LECTURER IN ZOOLOGY—The Registrar, The University, Nottingham (February 20).

LECTURER IN PHILOSOPHY; a LECTURER IN SOCIAL ANTHROPOLOGY; and an ASSISTANT LECTURER IN GEOGRAPHY—The Secretary, The Queen's University, Belfast (February 20).

LECTURER or ASSISTANT LECTURER IN THE DEPARTMENT OF APPLIED MATHEMATICS—The Registrar, The University, Liverpool (February 22).

LECTURER (preferably with an interest in biophysics) IN PHYSICS—The Secretary, St. Mary's Hospital Medical School (University of London), Paddington, London, W.2 (February 22).

ASSISTANT LECTURER IN MATHEMATICS (PURE or APPLIED)—The Principal, Royal Holloway College (University of London), Englefield Green, Surrey (February 25).

PRINCIPAL LECTURER and a SENIOR LECTURER IN THE DEPARTMENT OF MECHANICAL ENGINEERING; SENIOR LECTURERS (3) IN THE DEPARTMENT OF ELECTRICAL ENGINEERING; a LECTURER and an ASSISTANT LECTURER IN THE DEPARTMENT OF APPLIED PHYSICS; a SENIOR LECTURER IN METALLURGY and a LECTURER IN INORGANIC CHEMISTRY IN THE DEPARTMENT OF CHEMISTRY, METALLURGY AND TEXTILES—The Registrar, Lanchester College of Technology, Butts, Coventry (February 25).

LECTURER (with a good honours degree in electrical engineering or physics, and suitable experience in light-current electrical engineering and applied electronics) IN ELECTRICAL ENGINEERING—Joint Clerk to the University Court, Queen's College (University of St. Andrews), Dundee (February 27).

CHAIR AND HEADSHIP OF THE DEPARTMENT OF ZOOLOGY, and CHAIR AND HEADSHIP OF THE DEPARTMENT OF MINING—The Registrar, The University, Leeds 2 (February 29).

LECTURER or ASSISTANT LECTURER IN BIOCHEMISTRY—The Registrar, The University, Leeds (February 29).

LECTURER (with experience in archæological field work, and qualified particularly in British archæology) IN ARCHÆOLOGY—The Secretary and Registrar, University College of North Wales, Bangor, North Wales (February 29).

SCIENTIFIC OFFICERS/SENIOR SCIENTIFIC OFFICERS (analytical or inorganic chemists with a first- or second-class honours degree in chemistry or equivalent) IN THE LABORATORY OF THE GOVERNMENT CHEMIST, D.S.I.R., London, for analytical work including research into the development of advanced methods of analysis—The Ministry of Labour, Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting Ref. 487/9A (February 29).

RESEARCH ASSISTANTS (2) (with a first- or second-class honours degree in chemistry or Graduate Member of the Royal Institute of Chemistry) IN CHEMISTRY—The Registrar, Lanchester College of Technology, Butts, Coventry (March 1).

RESEARCH FELLOW IN CRYSTALLOGRAPHY (COMPUTING) in the School of Chemistry, to take charge of the coding and supervise the use of computer programmes for crystallographic calculations of the high-speed 'Silliac' computer—The Registrar, University of Sydney, Sydney, N.S.W., Australia (March 4).

IMPERIAL CHEMICAL INDUSTRIES RESEARCH FELLOW IN CHEMISTRY OR PHYSICS—The Registrar, The University, Leicester (March 5).

IMPERIAL CHEMICAL INDUSTRIES RESEARCH FELLOWS IN BIOCHEMISTRY, CHEMISTRY, ENGINEERING AND PHYSICS—The Secretary and Registrar, The University, Southampton (March 5).

LECTURER IN APPLIED MATHEMATICS—The Registrar, King's College (University of Durham), Newcastle-upon-Tyne (March 5).

ASSISTANT LECTURER (veterinary surgeon, or with a degree in physiology) IN THE DEPARTMENT OF PHYSIOLOGY—The Secretary, Royal Veterinary College (University of London), Royal College Street, London, N.W.1 (March 15).

LECTURER or ASSISTANT LECTURER IN BOTANY at the University of Malaya (Singapore Division)—The Secretary, Inter-University Council for Higher Education Overseas, 29 Woburn Square, London, W.C.1 (March 15).

CHAIR OF ZOOLOGY in the Imperial College of Tropical Agriculture, Trinidad, West Indies—The Secretary, Imperial College of Tropical Agriculture, 40 Norfolk Street, Strand, London, W.C.2 (March 17).

LECTURER (qualified in either pure or applied mathematics) IN MATHEMATICS—The Secretary of University Court, The University, Glasgow (March 19).

ASSISTANT LECTURER or LECTURER (with a strong interest in some branch of theoretical physics, or in information theory, or some other branch of applied mathematics) IN APPLIED MATHEMATICS—The Registrar, University College of South Wales and Monmouthshire, Cathays Park, Cardiff (March 21).

LECTURER or ASSISTANT LECTURER IN ZOOLOGY at the University of Hong Kong—The Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1 (Hong Kong and London, March 21).

LECTURERS IN PURE MATHEMATICS—The Secretary, The Queen's University, Belfast (March 21).

LECTURER (preferably with interests in theoretical electromagnetics and/or plasma theory) IN PHYSICS—The Secretary, The Queen's University, Belfast (March 30).

CHAIR OF BOTANY in the University of Hong Kong—The Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1 (Hong Kong and London, March 31).

ASSISTANT LECTURER (Grade "B") TO TEACH ORGANIC AND GENERAL CHEMISTRY—The Clerk to the Governors, Northern Polytechnic, Holloway, London, N.7.

ASSISTANT LECTURER IN BOTANY; an ASSISTANT LECTURER IN CHEMISTRY; an ASSISTANT LECTURER IN PHYSICS; an ASSISTANT LECTURER IN PHYSIOLOGY; and a RESEARCH ASSISTANT (qualified in biochemistry, physiology or zoology) TO THE PROFESSOR OF ZOOLOGY—The Secretary, Queen Elizabeth College (University of London), Campden Hill Road, London, W.8.

ELECTRONICS ENGINEER (Experimental Officer grade), to collaborate with research and instrument development in marine physics at Millport—The Secretary, Scottish Marine Biological Association, Millport, Isle of Cumbrae, Scotland.

EXPERIMENTAL OFFICER (preferably with a pass degree or H.N.C., and experience in electronic and optical recording techniques, or G.C.E. in five subjects, including two scientific or mathematical subjects at "A" level), to work in collaboration with scientists on shock and detonation wave phenomena using high speed electronic and optical equipment—The Senior Recruitment Officer, The Atomic Weapons Research Establishment, Aldermaston, Berkshire, quoting Ref. A.2366/34.

LECTURER IN MATHEMATICS; and a LECTURER IN STATISTICS AND MATHEMATICS—The Registrar, Bradford Institute of Technology, Bradford 7.

MASTER TO TEACH PHYSICS to Open Scholarship level—The Headmaster, Latymer Upper School, Hammersmith, London, W.6.

MASTER TO TEACH PHYSICS to Sixth Form standard—The Headmaster, Merchant Taylors' School, Sandy Lodge, Northwood, Middlesex.

SENIOR LECTURER (with a good honours or higher degree, with teaching and preferably appropriate industrial experience) IN THE DEPARTMENT OF CHEMISTRY AND METALLURGY, to teach inorganic chemistry to final B.Sc. and Part II Grad.R.I.C. level—The Principal, Rutherford College of Technology, Northumberland Road, Newcastle-upon-Tyne.

SENIOR TECHNICIAN IN THE BIOCHEMISTRY DEPARTMENT—The Secretary, Queen Mary's Hospital for the East End, Stratford, London, E.15.

SENIOR TECHNICIAN (preferably man 25–30 years of age, with biochemical and practical laboratory experience) for newly formed Research Department of Immunology—The Secretary, Wright–Fleming Institute, St. Mary's Hospital Medical School, Paddington, London, W.2.

REPORTS and other PUBLICATIONS

(not included in the monthly Books Supplement)

Great Britain and Ireland

Department of Scientific and Industrial Research. Food Investigation. Technical Paper No. 7: Quality Control in Marketing Fresh Poultry. By Dr. D. H. Shrimpton. Pp. iv+25. (London: H.M. Stationery Office, 1959.) 2*s.* net. [312

Eton College Natural History Society. Fourteenth Report, 1958–1959. Pp. 35+2 plates. (Eton: Eton College Natural History Society, 1959.) 2*s.* 6*d.* [312

Department of Scientific and Industrial Research: Building Research Station. National Building Studies Special Report. No. 30: A Study of Alternative Methods of House Construction. Pp. vi+93+19 plates. (London: H.M. Stationery Office, 1959.) 7*s.* 6*d.* net. [312

Department of Scientific and Industrial Research. Pest Infestation Research—Bulletin No. 1: Fumigation with Methyl Bromide Under Gas-Proof Sheets. By W. Burns Brown. Pp. vi+44+8 plates. (London: H.M. Stationery Office, 1959.) 4*s.* 6*d.* net. [312

Commonwealth Mycological Institute. Mycological Papers. No. 71: Studies on Cercospora and Allied Genera. I: *Cercospora* Species with Coloured Spore on *Phyllanthus* (Euphorbiaceae). By F. C. Deighton. Pp. 23. 9*s.* net. **No. 72: Clasterosporium and Some Allied Dematiaceae—Phragmosporæ. II.** By M. B. Ellis. Pp. 75. 25*s.* net. (Kew: Commonwealth Mycological Institute, 1959.) [312

Other Countries

United States Department of the Interior: Geological Survey. Bulletin 1039–C: Haydite Raw Material in the Kings River, Sutton, and Lawing Areas, Alaska. By Richard A. Ackhart and George Plafker. Pp. iv+33–65+plates 7–10. **Bulletin 1046–Q: Stratigraphy of Triassic and Associated Formations in Part of the Colorado Plateau Region.** By John H. Stewart, George A. Williams, Howard F. Albee, and Omer B. Raup. With a section on Sedimentary Petrology by Robert A. Cadigan. Pp. vi+487–576+plate 49. 65 cents. **Bulletin 1052–I: Equation in Continuity in Geology with Applications to the Transport of Radioactive Gas.** By A. Y. Sakakura, Carolyn Lindberg and Henry Faul. Pp. iv+287–305. 15 cents. **Bulletin 1058–G: Geology of the Mount Katmai Area, Alaska.** By A. Samuel Keller and Hillard N. Reiser. Pp. iv+261–298+plates 29–32. **Bulletin 1072–I: Beryl Deposits of the Beecher No. 3-Black Diamond Pegmatite, Custer County, South Dakota.** By Jack A. Redden. Pp. iii+537–559+plates 17 and 18. **Bulletin 1084–D: Geochemistry of Uranium in Phosphorates and Black Shales of the Phosphoria Formation.** By Richard P. Sheldon. Pp. iv+83–115. 20 cents. **Bulletin 1087–B: Uranium Resources of the Cedar Mountain Area, Emery County, Utah—A Regional Synthesis.** By Henry S. Johnson, Jr. Pp. iv+23–58. 20 cents. (Washington, D.C.: Government Printing Office, 1959.) [312

Berichte des Deitschen Wetterdienstes. Nr. 57 (Band 8): Ein Beitrag zu den Windverhältnissen in den ersten 100. der Atmosphäre. Von Rüdiger Trappenberg. Pp. 41. (Offenbach a.M.: Deutschen Wetterdienstes, 1959.) [312

Smithsonian Institution: United States National Museum. Bulletin 218: Contributions from the Museum of History and Technology, Papers 1 to 11. Pp. v+201. (Washington, D.C.: Government Printing Office, 1959.) 2.50 dollars. [312

National Academy of Sciences—National Research Council, Washington. Publication No. 713: Digest of Literature of Dielectrics, Vol. 22, 1958. Prepared by the Committee on Digest of Literature of the Conference on Electrical Insulation, Division of Engineering and Industrial Research. Edited by Robert A. Soderman and Louis J. Frisco. Pp. xiii+293. (Washington, D.C.: National Academy of Sciences—National Research Council, 1959.) 5 dollars. [312

Smithsonian Miscellaneous Collections. Vol. 139, No. 8: The Anatomical Life of the Mosquito. By R. E. Snodgrass. Pp. iii+87. (Publication 4388.) (Washington, D.C.: Smithsonian Institution, 1959.) [312

United States Department of Agriculture: Agricultural Research Service. Technical Bulletin No. 1203: Measuring Seepage from Irrigation Channels. By A. R. Robinson and Carl Rohwer. (Published in co-operation with the Colorado Agricultural Experiment Station, and the Bureau of Reclamation, United States Department of the Interior.) Pp. ii+82. (Washington, D.C.: Government Printing Office, 1959.) [312

Proceedings of the United States National Museum. Vol. 110, No. 3419: A Description and Classification of the Final Instar Larvæ of the Ichneumonidæ (Insects, Hymenoptera). By J. R. T. Short. Pp. 391–511. (Washington, D.C.: Government Printing Office, 1959.) [312

Comité International de Photobiologie. Bulletin No. 1, October 1959. Pp. 19. (Copenhagen: Dr. Bent Buchmann, Finsen Memorial Hospital, Strandboulevarden 49, 1959.) [312

Editorial and Publishing Offices of "NATURE"
MACMILLAN & CO., LTD.,
ST. MARTIN'S STREET, LONDON, W.C.2.
Telephone Number: Whitehall 8831. Telegrams: Phusis Lesquare London

Annual subscription £7/15/–, payable in advance, postage paid to any part of the world

Advertisements only should be addressed to
T. G. Scott & Son, Ltd., 1 Clement's Inn, London, W.C.2
Telephone Number: Holborn 4743

All rights reserved. Registered as a newspaper at the General Post Office